PROCEEDINGS

OF THE

ROYAL SOCIETY OF EDINBURGH.

VOL. XI. 1880–81. No. 108.

Ninety-Eighth Session.

GENERAL STATUTORY MEETING.

Monday, 22d *November* 1880.

Professor DOUGLAS MACLAGAN, Vice-President, in the Chair.

The following Council were elected:—

President.

The Right Hon. LORD MONCREIFF.

Vice-Presidents.

Principal Sir Alex. Grant, Bart.
David Milne Home, LL.D.
Sir C. Wyville Thomson, LL.D.
Prof. Douglas Maclagan, M.D.
Prof. H. C. Fleeming Jenkin, F.R.S
Rev. Dr Lindsay Alexander.

General Secretary—Professor Tait.

Secretaries to Ordinary Meetings.

Professor Turner.
Professor Crum Brown.

Treasurer.—A. Gillies Smith, C.A.

Curator of Library and Museum—Alexander Buchan, M.A.

Councillors.

J. Y. Buchanan, M.A.
Rev. Thomas Brown.
Robert Gray, Esq.
Dr William Robertson.
Professor Campbell Fraser.
Professor Geikie.
Rev. Dr Cazenove.
David Stevenson, M.I.C.E.
Professor Chrystal.
Alexander Forbes Irvine of Drum.
Professor A. Dickson.
The Right Rev. Bishop Cotterill.

By a Resolution of the Society (19th January 1880) the following Hon. Vice-Presidents, having filled the office of President, are also Members of the Council:—

His Grace the DUKE of ARGYLL, K.T., D.C.L.
Sir ROBERT CHRISTISON, Bart., M.D., D.C.L.
Sir WM. THOMSON, LL.D., D.C.L., F.R.S., Foreign Associate of Inst. of France.

Monday, 6th December 1880.

The Right Hon. LORD MONCREIFF of Tulliebole, LL.D., President, occupied the Chair, and opened the Session with an Introductory Address on the Rise of the Constitutional Idea.* Bishop Cotterill proposed that the Society record a vote of thanks to the President, which was agreed to.

The following Communications were read:—

1. On the Structure of *Euplectella*. By Dr F. E. Schültze. Communicated by Sir Wyville Thomson.

2. On Equidifferent Multiples of Irrational Quantities. By Mr E. Sang.

Our attention, naturally, is most drawn to the difficult parts of an inquiry; the easier steps are apt to be overlooked. Thus, while much attention and deep thought have been bestowed on the solution of equations, on the computation of logarithms, on the construction of astronomical canons; such a simple process as the repeated addition of some known quantity, has not been considered worthy of the notice of arithmeticians. Yet the tables constructed by help of this process are much more numerous, and are as important as the others, often indeed serving as their foundation.

The case when the quantity to be added is expressed accurately in numbers, needs no remark; but when that quantity is represented only approximately, we have to consider the accumulation of that part which is unavoidably left off, and to see that this does not lead to an error of so much as the half of unit in the last place that is to be retained.

The obvious and indeed the common plan is to carry the scroll calculations to several places beyond what are to be preserved, and to rewrite the whole leaving off the surplus figures, only taking care to augment the last figure whenever those to be rejected exceed 5000 . . . . . Or, if the scroll calculation be put in the compositor's hands, to trust to his care and to that of the reader, in making the requisite augmentations.

* The first part of the President's Opening Address will be given along with the second part.

Thus, let it be proposed to construct a table of the Sun's mean daily motion in longitude, true to the nearest hundredth part of a second of the modern division. Taking the length of the equinoctial year as 365·242217 mean solar days, the motion in one day is 1‘ 09′ 51″ 63‴ 6513585 or, as is far within the accuracy of our knowledge,

1‘ 09′ 51″ 63‴ 65136.

We should then write this number on the lower edge of a card, and make the successive additions as under :—

1	1	09	51	63	65136
2	2	19	03	27	30272
3	3	28	54	90	95408
4	4	38	06	54	60544
5	5	47	58	18	25680
6	6	57	09	81	90816
7	7	66	61	45	55952
8	8	76	13	09	21088
9	9	85	64	72	86224
10	10	95	16	36	51360

separating the redundant figures by a line, and afterwards making the requisite augmentations.

In order to lessen the labour of such work, I have for many years used two simple artifices, and find among my papers that these were applied in 1845 to the formation of tables of the equivalent values of solar and sidereal time.

The first of these artifices is to augment the initial value by ·50000; by this means the requisite augmentations are made throughout, and we have only to reject the surplus figures; or, if these have been written on a slip of paper placed alongside, to remove that slip :—thus

days.	‘	′	″	‴	
0	0	00	00	00	50000
1	1	09	51	64	15136
2	2	19	03	27	80272
3	3	28	54	91	45408
4	4	38	06	55	10544
5	5	47	58	18	75680
6	6	57	09	82	40816
7	7	66	61	46	05952
8	8	76	13	09	71088
9	9	85	64	73	36224
10	10	95	16	37	01360

The second artifice is founded on the well-known properties of chain-fractions.

When we use Lord Brouncker's process in approximating to the value of an irrational quantity, we obtain a series of fractions alternately too great and too small, having this property that the difference between two contiguous members of the series is a fraction having unit for its numerator, and for its denominator the product of the two denominators. Hence it follows, that the error of the last obtained fraction is much less than unit divided by the square of its denominator; and thus a Brounckerian fraction having only three figures in its denominator will give as much precision as a decimal fraction of five places.

On treating the above residue ·6513585 by Brouncker's method we get the fraction $\frac{1007}{1546}$, of which the value is ·65135834; hence if we use the addend 1 09 51 63 $\frac{1007}{1546}$, beginning with 00 $\frac{773}{1546}$, we shall obtain the required table on merely rejecting the fractions.

We also avoid the need for writing the denominator by placing on the lower edge of the card the equivalent expressions:—

	'	'	"	‴			
	1	09	51	63	+	1007	
and	1	09	51	64	−	539	thus
0	0	00	00	00		773	
1	1	09	51	64		234	
2	2	19	03	27		1241	
3	3	28	54	91		702	
4	4	38	06	55		163	
5	5	47	58	18		1170	
6	6	57	09	82		631	
7	7	66	61	46		92	
8	8	76	13	09		1099	
9	9	85	64	73		560	
10	10	95	16	37		21	

Here we observe that for the 773d day the fractional remainder will be 0, and that, therefore, we are in doubt whether to write 03‴ · 0 or 02‴ 1546. From the rank of the fraction in the Brounckerian series we perceive that it is in defect; wherefore we choose the former of the two. The same thing will recur at the 2319th day. Had the fraction been in excess, we should have written 02″ with 1546 over.

When the denominator of the approximate fraction is small, the same series of remainders may recur often during the work. In

that case it is convenient to write them on a joined ribbon of paper, which may be passed over and under the page on which we are working; in this way the repeated writing of the remainders is saved. The saving thereby is considerable; thus in the computation of the tables for converting solar into sidereal time, and conversely, the writing of eighty-six thousand figures was spared.

The above example sufficiently explains the principles and the application of the artifice.

3. Algebra of Relationship.—Part II. By A. Macfarlane, M.A., D.Sc., F.R.S.E.

(Received October 19, read December 6, 1880.)

At the end of my previous paper on the Algebra of Relationship (Proc. Roy. Soc. Edinb., vol. x. p. 224), I promised to return to the investigation of the subject, as it seemed capable of further extension. This anticipation has proved correct, and I have now the honour of bringing before the Society the further developments I have made.

In this investigation we consider a particular class of objects, and that class is in its widest extent *mankind*, by which term I mean the entire number of men who have existed, exist, or will exist. The universal properties of the symbols are deduced from the universal properties of mankind. In our consideration of this universe of mankind, we restrict our attention to the classes into which it is divided by qualities depending on ties of anterior or of posterior relationship, that is, of consanguinity or of affinity.

The italic capitals A, B, C, &c., are used to denote the names of the individuals within this universe. They are singular terms, or, in other words, selective symbols which operating within or upon U, select each only one individual. They are subject to the laws

$$A+B=B+A;$$
$$A^2=0;$$
$$\text{and } AB=0, \text{ unless } B=A;$$

where the sign $=$ means *identical with*.

In my previous paper, I based the investigation on four fundamental symbols s, d, σ, δ, denoting respectively *sons of a man*,

daughters of a man, sons of a woman, and *daughters of a woman.* For example, sA was used to denote the sons of the man A. Thus the symbol sA selects a portion of the universe of mankind, and that portion embraces no, one, or more than one individual. We have seen that the symbol A is also selective, but embracing only one individual. The symbol s is different; it may be considered as indicating to the mind to pass from A to sA. It is convenient to have words to express the relations of these symbols to one another. The expression sA may be called a *term,* A the *origin* of the term, and s the *relationship* of the term. In this paper I proceed mainly by means of the two more general fundamental relationships c and γ, where c denotes *the children of a man,* and γ *the children of a woman.*

Let $cA = B + C + D$. This statement is a logical equation; it asserts that the children of the man A are B and C and D, and only these. Let $cA > B + C + D$. This statement is a logical inequation; it asserts that the children of the man A include B and C and D. Let $cA < B + C + D$. This statement is a logical inequation; it asserts that the children of the man A are included in B and C and D.

What is the proper meaning of $\frac{1}{c}A$ and $\frac{1}{\gamma}A$? The term $\frac{1}{c}A$ means *the father of the person A.* It is a singular term by reason of physiological laws which apply to mankind. There are other functional symbols, whose reciprocals may form plural terms; for example, let eA denote the employés of A, then $\frac{1}{e}B$ may denote the employers of B.

The meaning of ccA follows from the meaning we have attached to cA. It means the children of the sons of the man A. Similarly the terms γcA, $c\gamma B$, $\gamma\gamma B$ denote respectively the children of the daughters of the man A, the children of the sons of the woman B, and the children of the daughters of the woman B. The symbol c operating on cA, directs us first to select the male children of A, and then to take the children of each of these. Similarly γ, operating on cA, directs us first to select the female children of A, and then to take their children. Thus the symbols c and γ, in so far as they are selective in their operation, partake of the nature of the quaternion symbols S and V.

The relationship cc may be denoted without ambiguity by c^2, and $\frac{1}{c}$ by c^{-1}; and generally an index may be used to denote the number of times c or γ is repeated, whether directly or inversely.

The meaning of each of the permutations of the four symbals c, γ, c^{-1}, γ^{-1} two together, with one another, and with themselves, is given in Table II. (p. 12.) In the first row we have the different species of grandchildren. In the second row we have $c^{1-1}A$ and $\gamma^{1-1}A$, which denote respectively the children of the father of A, and the children of the mother of A; hence the two species of brothers and sisters, the origin being included as a special case. We have also $c\gamma^{-1}A$ and $\gamma c^{-1}A$, which denote the children by male descent of the mother of A, and the children by female descent of the father of A; each of which must always have the value 0, on account of the monœcious nature of mankind. Any term in which either $c\gamma^{-1}$ or γc^{-1} occurs whether singly or in combination has the value 0, on account of the morphological law referred to. In the third row we have $c^{-1+1}A$ and $\gamma^{-1+1}B$, which denote respectively the father of the children of the man A, and the mother of the children of the woman B; they are therefore equivalent to A and to B. Of the other two terms $c^{-1}\gamma B$ denotes the fathers of the children of the woman B, and $\gamma^{-1}cA$ denotes the mothers of the children of the man A. Thus the terms of this row break up into two groups denoted respectively by *consorts* and *self.* The terms belonging to the latter group are enclosed. In the fourth row we have the expressions for the grandparents.

In Table III. I have written out all the terms which are expressed by three symbols, omitting those which are null from containing $c\gamma^{-1}$ or γc^{-1}. The terms in the first row are the terms of the expansion of $(c+\gamma)^3$; those in the second row of $(c+\gamma)^2\left(\frac{1}{c}+\frac{1}{\gamma}\right)$; those in the third of $(c+\gamma)\left(\frac{1}{c}+\frac{1}{\gamma}\right)(c+\gamma)$, and so on. The method of deriving the terms is evidently exhaustive, and it supplies us not only with a means of denoting all possible relationships, but also of classifying them in a scientific manner. It will be convenient to have words to denote the different classes and sub-classes, and for this purpose I propose to employ the classificatory terms—Order, Genus, Species, Variety. By the *order* of a relationship I mean the number of symbols required to express it; for example, those of

Table III. are all of the third order. The classes in one row may be said to form one *genus*, and each class itself to be a *species*. Let c and γ be considered equivalent, then the index of each term in one row is the same; this is the generic property. The specific property depends on the differences expressed by c and γ. The *varieties* of a species are obtained by introducing the distinction of gender at any place where the form of expression for the species has left it unrestricted. For example, c^3A admits of two varieties, namely sc^2A and dc^2A—the sons of the sons of the sons of A, and the daughters of the sons of the sons of A.

The notions for the different genera of the third order are exhibited in the side column. That for the first genus is *great grandchildren;* that for the second is, in its widest extent, *grandchildren of parents*, but if the cases in which the species reduce to species of the first order be removed, then the genus-notion is that of *nephews* and *nieces.* The notion of the third genus is *children of parents of children.* The enclosed species, which are affected by containing c^{-1+1} or γ^{-1+1} express only *children;* the other species express *step-children* or *children.* Similarly for the other genera.

Another notion useful to consider and for which a name is required, is the number of generations between the individuals represented by a term and the origin of the term. For example, in c^3A the individuals represented by c^3A are removed by three generations from A; in $c^{2-1}A$ by only one generation. This number may be called the *interval* of the relationship. It is the sum of the indices of the term, and is constant for all the species of one genus.

Relationships may also be classified according to the direct or inverse form of the first symbol, and the subsequent number of changes from the one to the other. For instance, in $c^{2-2}A$ we have the first symbol direct, and only one subsequent change. Here A and the individuals represented by the term, have a common ancestor; in $c^{-2+2}A$ they have a common descendant. In the expressions for the relationships, let c and γ be considered equivalent, and the indices summed in accordance; then by neglecting the numbers but retaining the signs of the index, we shall obtain an expression for the quality we are considering, which may be called the *sign* of the relationship. The sign may begin with either + or −, and may end with either, but it must have

them in alternate succession. The sign of $c\gamma c$ is $+$, of c^{2-1} $+\ -$, of $c\gamma^{1-1}c^{-1}$ $+\ -$, of $c^{-1}\gamma^{1-1}c$ $-\ +\ -\ +$, and so on. The term *degree* may be used to denote the number of pluses and minuses in a sign, and *positive* to denote that the sign begins with $+$ and *negative* to denote that it begins with minus.

Relationship terms, inasmuch as they select a number of individuals from the universe of mankind in such a way that the same individual is selected only once, are qualitative symbols of the kind first discussed by Boole, and which I have treated of in my book on the "Algebra of Logic." They are therefore subject to the laws and processes of that Algebra.

That Algebra supplies us with the mode of formation of a compound term. Suppose that cA and γB have some members in common; these are classed together by the expression $cA\gamma B$, where cA and γB stand to each other in the relation of simultaneous multiplication, a relation quite different from that existing between c and A in cA. We may have compound terms of any degree of complexity, and the word *degree* may be used as meaning the number of simple terms in a compound term. The number of origins in a compound term is the same as the degree, but some of them may be coincident. The different compound terms of the second degree, each simple term being of the first order, are the following:—

$cBcA$	$cB\gamma A$	γBcA	$\gamma B\gamma A$
$cBc^{-1}A$	$cB\gamma^{-1}A$	$\gamma Bc^{-1}A$	$\gamma B\gamma^{-1}A$
$c^{-1}BcA$	$c^{-1}B\gamma A$	$\gamma^{-1}BcA$	$\gamma^{-1}B\gamma A$
$c^{-1}Bc^{-1}A$	$c^{-1}B\gamma^{-1}A$	$\gamma^{-1}Bc^{-1}A$	$\gamma^{-1}B\gamma^{-1}A$

The permutations $cB\gamma A$ and γBcA are not different in form; for the order of the components in a compound term is inessential. In the case of the extremes of the first row, the origins B and A must be identical, else the terms are null. In the case of the middle terms of that row the origins must be different, and different in sex. In the case of the terms of the second and third rows, the origins must be different. In the fourth row the extreme terms may have origins the same or different, and the middle terms never exist.

Thus certain compound terms are non-existent on account of natural laws; there are others which are non-existent, where certain

moral laws are observed. For example, $cA\gamma c^{1-1}A$ and $cA\gamma^{2-1}A$ are necessarily non-existent where the Christian laws of marriage are observed.

As an example of the manner in which the notation of this paper may be used, I shall employ it to find the different compound genera species and varieties of the term *cousin*. The word cousin in its general sense means any relationship of the sign $m-n$ where m and n is each not less than 2. When both of them are two, we have the relationship cousin in its strictest sense; when both are 3 we have second cousin, and I suppose that $2-3$ and $3-2$ have to be expressed by means of the same phrase. But by putting in the particular numbers for m and n, we obtain a simple and perfect means of specifying all the possible elementary forms of the notion. I shall restrict the elementary form of the word to the form $2-2$, which coincides with the fourth genus of the fourth order of relationships (the notion of which is grandchildren of grandparents), provided we exclude all the instances in which that genus reduces to genera of a lower order.

The different species are,

$$c^{2-2},\ c^{2-1}\gamma^{-1},\ c\gamma^{1-1}c^{-1},\ c\gamma^{1-2},\ \gamma c^{1-2},\ \gamma c^{1-1}\gamma^{-1},\ \gamma^{2-1}c^{-1},\ \gamma^{2-2};$$

and suppose them numbered consecutively from left to right. The different combinations of these species two together form the compound genus of the second degree. The number of species in this compound genus is 28, but certain of them do not exist on account of the moral laws

$$c^{-2}Ac^{-1}\gamma^{-1}A=0 \text{ and } \gamma^{-1}c^{-1}A\gamma^{-2}A=0,$$

or their equivalent forms,

$$\gamma cAc^{2}A=0, \text{ and } \gamma^{2}Ac\gamma A=0.$$

The non-existent species are 12, 15, 26, 34, 37, 48, 56, 78. There are 20 left. The number of species in the compound genus of the third degree is naturally 56, but by the above laws it is reduced to 16. For that of the fourth degree the numbers are 70 and 4 respectively. The four are 1368, 1467, 2358, 2457, each of which represents what ought to be meant by the phrase a *full cousin;* for all the higher compound genera are non-existent. Each species of each of these compound genera may contain four varieties; for the

individuals of the term may be male or female, and the origin of the term may be male or female. Thus the word *cousin*, restricted to mean having one or more common ancestors two generations back on either side, may have any one of 48 significations when it expresses a relationship between two persons each of given sex; and when the sex of neither is given it may have any one of 192 significations.

The method of this paper gives us a scientific classification of a man's feminine relations, which is of special interest at the present time, when the laws of marriage are under consideration. He is excluded by the table of degrees from marrying any one belonging to the classes marked with an asterisk.

ORDER

I. Gen. 1, Daughter*; 2, Mother*.

II. ,, 1, Granddaughter; 2, Sister*; 3, Wife; 4, Grandmother*.

III. ,, 1, Great-granddaughter*; 2, Niece*; 3, Stepdaughter*; 4. Aunt (by consanguinity*); 3, Wife of son*; 6, Stepmother*; 7, Mother of wife*; 8, Great-grandmother.

IV. ,, 1, Great-great-granddaughter; 2, Great-granddaughter of parent; 3, Daughter of step-child*; 4, Cousin; 5, Daughter of child-in-law; 6, Daughter of step-parent; 7, Sister of wife*; 8, Daughter of great-grandparent; 9, Wife of grandson*; 10, Wife of brother*; 11, (Necessarily masculine); 12, Step-grandmother*; 13, Grandmother of grandchild; 14, Mother of step-parent; 15, Grandmother of wife*; 16, Great-great-grandmother.

V. ,, 1. Great-great-great-granddaughter; 2, Granddaughter of nephew or niece; 3, Great-granddaughter of wife; 4, Daughter of cousin; 5, Granddaughter of consort of child; 6, Granddaughter of consort of parent; 7, Niece of wife*; 8, Niece of grandparent; 9, Daughter of consort of grandchild; 10, Daughter of consort of brother or sister; 11, Daughter of husband of wife; 12, Daughter of consort of grandparent; 13, Sister of consort of child; 14, Sister of consort of parent; 15, Aunt of wife*; 16, Aunt of grandparent; 17, Wife of great-grandson; 18, Wife of nephew*; 19, Wife of stepson; 20, Wife of uncle*; 21, Wife of husband of daughter; 22, Wife of husband of mother; 23, Wife of father of wife; 24, Wife of great-grandfather; 25, Mother of consort of grandchild; 26, Mother of consort of brother or sister; 27, Mother of husband of wife; 28, Mother of consort of grandparent; 29, Grandmother of consort of child; 30, Grandmother of consort of parent; 31, Great-grandmother of wife; 32, Great-great-great-grandmother.

I have to express my obligations to Professor Jevons' "Principles

of Science" for references to the papers on the Logic of Relation by Peirce, De Morgan, Ellis, and Harley. The philosophers mentioned discuss relation in general; I have restricted myself to the more definite subject of relation of men by consanguinity or affinity.

TABLE I.—*Relationships of the First Order.*

Children, . . .	c Children of a man.	γ Children of a woman.
Parents, . . .	$\frac{1}{c}$ Father of a person.	$\frac{1}{\gamma}$ Mother of a person.

TABLE II.—*Relationships of the Second Order.*

Grandchildren, . .	c^2 Children of sons of a man.	$c\gamma$ Children of sons of a woman.	γc Children of daughters of a man.	γ^2 Children of daughters of a woman.
Children of parents (Brothers and sisters),	c^{1-1} Children of the father of.	$c\gamma^{-1}$ $=0$.	γc^{-1} $=0$.	γ^{1-1} Children of the mother of.
Parents of children (Consorts—self.)	c^{-1+1} $=1$.	$c^{-1}\gamma$ Fathers of the children of a woman.	$\gamma^{-1}c$ Mothers of the children of a man.	γ^{-1+1} $=1$.
Grandparents, . .	c^{-2} Father of the father of.	$c^{-1}\gamma^{-1}$ Father of the mother of.	$\gamma^{-1}c^{-1}$ Mother of the father of.	γ^{-2} Mother of the mother of.

TABLE III.—*Relationships of the Third Order.*

Great-grandchildren, . .	c^3	$c^2\gamma$	$c\gamma c$	$c\gamma^2$	γc^2	$\gamma c\gamma$	$\gamma^2 c$	γ^3
Grandchildren of parents (Nephews and nieces),	c^{2-1}			$c\gamma^{1-1}$	γc^{1-1}			γ^{2-1}
Children of parents of children (Stepchildren—children),	c^{1-1+1}	$c^{1-1}\gamma$					$\gamma^{1-1}c$	γ^{1-1+1}
Children of grandparents (Uncles and aunts by blood),	c^{1-2}	$c^{1-1}\gamma^{-1}$					$\gamma^{1-1}c^{-1}$	γ^{1-2}
Parents of grandchildren (Children-in-law—children),	c^{-1+2}	$c^{-1+1}\gamma$	$c^{-1}\gamma c$	$c^{-1}\gamma^2$	$\gamma^{-1}c^2$	$\gamma^{-1}c\gamma$	$\gamma^{-1+1}c$	γ^{-1+2}
Parents of children of parents (Stepparents—parents,)	c^{-1+1-1}			$c^{-1}\gamma^{1-1}$	$\gamma^{-1}c^{1-1}$			γ^{-1+1-1}
Grandparents of children (Parents-in-law—parents),	c^{-2+1}	$c^{-2}\gamma$	$c^{-1}\gamma^{-1}c$	$c^{-1}\gamma^{-1+1}$	$\gamma^{-1}c^{-1+1}$	$\gamma^{-1}c^{-1}\gamma$	$\gamma^{-2}c$	γ^{-2+1}
Great-grandparents, . .	c^{-3}	$c^{-2}\gamma^{\,1}$	$c^{-1}\gamma^{-1}c^{-1}$	$c^{-1}\gamma^{-2}$	$\gamma^{-1}c^{-2}$	$\gamma^{-1}c^{-1}\gamma^{-1}$	$\gamma^{-2}c^{-1}$	γ^{-3}

BUSINESS.

Dr T. A. Wise and Mr Thomas Gray were balloted for, and declared duly elected Fellows of the Society.

Monday, 20th December 1880.

SIR WYVILLE THOMSON, F.R.S., Vice-President, in the Chair.

The following Communications were read :—

1. On Dust, Fogs, and Clouds. By Mr John Aitken.

(*Abstract*).

Dust, fogs, and clouds seem to have but little connection with each other, and we might think they could be better treated of under two separate and distinct heads. Yet I think we shall presently see that they are more closely related than might at first sight appear, and that dust is the germ of which fogs and clouds are the developed phenomena.

This was illustrated by an experiment in which steam was mixed with air in two large glass receivers; the one receiver was filled with common air, the other with air which had been carefully passed through a cotton-wool filter and all dust removed from it. In the unfiltered air the steam gave the usual and well-known cloudy form of condensation, while in the filtered air no cloudiness whatever appeared. The air remained supersaturated and perfectly transparent.

The difference in the behaviour of the steam in these two cases was explained by corresponding phenomena, in freezing, melting, and boiling. It was shown that particles of water vapour do not combine with each other to form a cloud-particle, but the vapour must have some solid or liquid body on which to condense. Vapour in pure air therefore remains uncondensed or supersaturated, while dust-particles in ordinary air forms the nuclei on which the vapour condenses and forms fog or cloud-particles.

This represents an extremely dusty condition of the air, as every

fog and cloud-particle was formerly represented by a dust-particle, which vapour by condensing upon it has made visible. When there is much dust in the air but little vapour condenses on each particle, and they become but little heavier, and easily float in the air. If there are few dust specks each gets more vapour, is heavier, and falls more quickly.

These experiments were repeated with an air-pump, a little water being placed in the receiver to saturate the air. The air was then cooled by slightly reducing the pressure. When this is done with unfiltered air a dense cloudiness fills the receiver; but when with pure air no fogging whatever takes place, there being no nuclei on which the condensation can take place. In this experiment, and in the one with steam, the number of cloud-particles is always in proportion to the dust present. When the air is nearly pure and only a few dust-particles present, then only a few cloud-particles form, and they are heavy and fall like fine rain.

The conclusions drawn from these experiments are—1st, That whenever water vapour condenses in the atmosphere it always does so on some solid nucleus; 2d, that dust-particles in the air form the nuclei on which the vapour condenses; 3d, that if there was no dust there would be no fogs, no clouds, no mists, and probably no rain, and that the supersaturated air would convert every object on the surface of the earth into a condenser on which it would deposit; 4th, our breath when it becomes visible on a cold morning, and every puff of steam as it escapes into the air, show the impure and dusty condition of our atmosphere.

The source of the fine atmospheric dust was then referred to, and it was shown that anything that broke up matter into minute parts would contribute a share. The spray from the ocean, when dried and converted into fine dust, was shown to be an important source. Meteoric matter also probably contributed a proportion. Attention was then directed to the power of heat and combustion as a source of this fine dust.

It was shown that if there is much dust, then each particle only gets a little vapour condensed upon it, that when the particles are numerous they become but little heavier, and easily float in the air, and give rise to that close packed but light form of condensation which constitutes a fog, and therefore whatever increases the amount

of dust in the air tends to increase fogs, and that when the dust-particles are not so numerous the cloud-particles are larger, and settle down more quickly.

It was shown that by simply heating any substance such as a piece of glass, iron, brass, &c., a cloud of dust was driven off, which, when carried along with pure air into the experimental receiver, gave rise to a dense fog when mixed with steam. So delicate is this test for dust, that if we heat the one-hundredth of a grain of iron wire, the dust driven off from it will give a distinct cloudiness in the experimental receiver, and if we take the wire out of the apparatus and so much as touch it with our fingers and again replace it, it will again be active as a cloud-producer. Many different substances were tried, and all were found to be active fog-producers. Common salt is perhaps one of the most active.

Heat, it is well known, destroys the motes in the air, and it might be thought that flame and other forms of combustion ought to give rise to a purer air. Such, however, is not the case. Gas was burned in a glass receiver, and supplied with filtered air for combustion, and it was found that the products of combustion of pure air and dustless gas gave rise to an intensely fog-producing atmosphere. It may be mentioned here that the fog-producing air from the heated glass, metals, and burning gas, were each passed through the cotton-wool filter, and the air was in all cases made pure, and did not give rise to cloudiness when mixed with steam.

It will be seen that it is not the dust motes which are revealed to us by a beam of sunlight when shining into a darkened room, that form the nuclei of fog and cloud-particles, as these may be entirely removed by heat, and yet the air remain active as a cloud-producer. The heat would seem to break up the larger motes which reflect the light into smaller and invisible ones. When speaking of dust, it is to these infinitesimally small and invisible particles we refer. The larger motes which reflect the light will no doubt be active nuclei, but their number is too small to have any important effect.

It is suggested, and certain reasons are given for supposing that the blue colour of the sky is due to this fine dust.

Other experiments were made to test the fog-producing power of the air and gases from different sources. The air to be tested was

introduced into the experimental receiver and mixed with steam, and the relative densities of the fog produced were noted. It was found that the air of the laboratory where gas was burning always gave a denser fog than the air outside, and that the air outside varied, giving less fog during wet than during dry weather. The products of combustion of gas burned in a Bunsen flame, a bright flame, and a smoky flame, were all tested and found to be about equally bad, and all much worse than the air in which they were burned. Products of combustion from a clear fire and from a smoky one gave about equal fogging, and both much worse than the air of the room.

Experiments were made by burning different substances. Common salt when burned in a fire or in alcohol flame gave an intensely fog-producing atmosphere, but burned sulphur was the most active substance experimented on. It gave rise to a fog so dense it was impossible to see through a thickness of 5 cm. of it.

The vapours of other substances than water were tested to see if they would condense in the cloud form without nuclei on which to deposit. All the substances experimented on, which included sulphuric acid, alcohol, benzole, and paraffin, only gave a cloudy condensation when mixed with ordinary unfiltered air, and remained perfectly clear when mixed with filtered air, all these acting like water vapour.

Before referring to fogs, which have now become so frequent and aggravated in our large towns, it was pointed out that caution was necessary in applying the results of the experiments.

The conditions of a laboratory experiment are so different, and on so small a scale, that it is not safe to carry their teaching to the utmost limits, and apply them to the processes which go on in nature. We may, however, look to the experiments for facts from which to reason, and for processes which will enable us to understand the grander workings of nature.

It having been shown that vapour, by condensing on the dust-particles in the air, gives rise to a fogging, the density of which depends on the amount of fine dust in the air, the more dust the finer are the fog-particles, and the longer they remain suspended in the air. It having been also shown that all forms of combustion, perfect and imperfect, are producers of fog nuclei, it is concluded

that it is hopeless to expect that, adopting more perfect forms of combustion than those at present in use, we shall thereby diminish the frequency, persistency, or density of our town fogs. More perfect combustion will, however, remove the pea-soup character from the fogs and make them purer and whiter, by preventing the smoke which at present mixes with our town fogs and aggravates their character, and prevents them dissolving when they enter our rooms. Smoke descends during a fog, because the smoke particles are good radiators, and soon get cooled and form nuclei on which the water vapour condenses. The smoke thus becomes heavier and falls. This explains why it is falling smoke is often a sign of coming rain. It indicates a saturated condition of the atmosphere.

Sulphur when burned has been shown to be an intensely active fog-producer. Calculation shows that there are more than 200 tons of sulphur burned with the coal every winter day in London, a quantity so enormous as quite to account for the density of the London fogs. It is suggested that some restriction ought to be put on the amount of sulphur in the coal used in towns.

Before utterly condensing the smoke and the sulphur, it was pointed out that it would be necessary thoroughly to investigate, and fully to consider the value of smoke as a deodorizer, and also the powerful antiseptic properties of the sulphurous acid formed by the burning sulphur. The air during fogs is still and stagnant. There is no current to clear away the foul smells and deadly germs that float in the air, and which might be more deadly than they are were it not for the suspended soot and burned sulphur. We must therefore be on our guard lest we substitute a great and hidden danger for an evident but less evil.

2. Solar Eclipse, 31st December 1880. By Mr E. Sang.

The elements for the compution of eclipses are given in the "Nautical Almanac" with precision sufficient for all ordinary purposes; but, when we wish to compare the lunar ephemeris with actual observation for the purpose of verifying or of improving our data, we must go somewhat more minutely into the investigation.

Thus, in the List of Elements, p. 403, the changes in the right-ascension and declination of the sun and moon are supposed to be

proportional to the times, while the moon's geocentric semidiameter, as well as the horizontal parallax, is supposed to be constant during the eclipse. In this way some exceedingly small errors are introduced into the calculation.

In order to take full advantage of the admirably minute and exact ephemerides given in the body of the "Almanac," I thence, using second differences wherever they had any influence, computed the geocentric positions of the sun and moon, and the moon's parallax and semidiameter, for intervals of 10 m. during the eclipse.

From these again I deduced strictly the declinations, hour angles, semidiameters, and separations, as seen from the Royal Observatory of Edinburgh, using 300 : 299 as the ratio of the earth's oblateness. Lastly, from these results, and with the same precautions, I calculated the instants of the first and last contacts, and that of the closest approach. My table of the values of circular segments enables me also, with great ease, to determine the part of the sun's disc hid by the moon.

The following are the results :—

	H.	M.	S.	
First contact at	1	30	10	Green. M. S. Time
Greatest phase,	2	29	26	,,
Last contact,	3	26	15	,,

Portion of sun's diameter uncovered 17′ 03″. Ratio of uncovered to covered portions of sun's disc 631 : 369, the whole surface being 1,000.

I may remark that the moon's parallax and semidiameter, as given among the elements, have been obtained by simple interpolation from those for 0 h. and 12 h.; whereas the moon is in perigee during the eclipse, and the parallax instead of decreasing uniformly from 0 h. till 12 h., actually increases to a maximum and then decreases; so that in place of 61′ 27″·3 we should have had 61′ 27″.6.

The comparison of these predictions with the times observed at the Calton Hill will be interesting, should the weather permit.

2. On the Preparation of Adamantine Carbon or Diamond. By R. Sydney Marsden, D.Sc., F.R.S.E., F. Inst. Chem., &c.

(*Preliminary Notice.*)

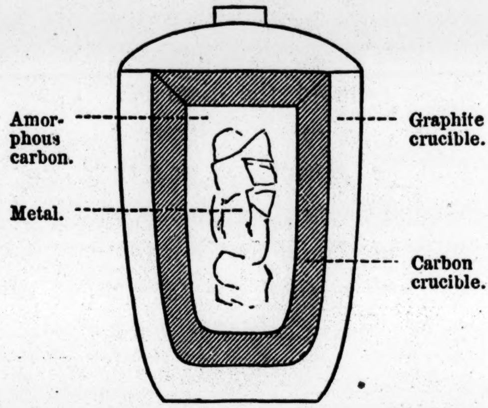
The preparation of adamantine carbon or diamond has exercised the genius of philosophers from the very earliest times; but it was not until the middle of the last century (1772) that Lavoisier established the diamond's true nature—notwithstanding the simplicity of the experiments required to demonstrate the fact—and showed it to consist of pure carbon in a crystallised state. Since that time very many attempts have been made to prepare it artificially, but until the recent and now famous experiments of Mr J. B. Hannay there has not been the slightest approach towards the solution of this problem. Great obstacles stood in the way of success, the chief being the complete insolubility of carbon in all known liquids, coupled with its non-volatility and infusibility; while the subject was rendered even more difficult and obscure, by ignorance of the conditions under which the diamond is produced in nature, its peculiar crystalline form, together with extreme rarity, indicating a probable very slow formation, and rare natural existence of the conditions necessary for its formation.

The process employed by me for the production of this substance is identical with the one for the preparation of pure adamantine boron which was worked out by Dr R. M. Morrison and myself, and communicated to this Society in a paper read June 17, 1878. It consists in dissolving the amorphous variety in fused silver or an alloy of platinum and silver, and allowing it to crystallize out again on cooling. This is effected in the following manner:—

First of all we take a graphite crucible and line it inside with a layer of pure carbon half an inch in thickness—the carbon employed for this purpose is pure sugar charcoal mixed with a solution of gum into a firm paste and then tightly packed into the crucible, this is then very slowly dried and ultimately heated red-hot and allowed to cool again—the centre portion scooped out leaving the lining of half an inch thick, firm, solid, and compact, and without any cracks or holes; to this special attention must be paid.

The amorphous carbon (which is pure sugar charcoal prepared by

calcining sugar) is then reduced to an impalpable powder in an agate mortar, and laid in alternate layers with the metal (in small lumps) in the carbon crucible as already described, great pains being taken to secure that the metal is well surrounded with carbon. The carbon lid is then tightly fitted, and any little crevice filled up with pure charcoal. The graphite crucible lid luted on with the mixture of carbon and gum and the whole again carefully dried. This graphite crucible is then placed in an ordinary steel melting crucible (to facilitate its being handled) and surrounded with charcoal and coke-dust. The whole then placed in a Siemens' regenerative gas furnace and kept at the temperature of melting steel for from nine to ten hours. It is then taken out and the crucible buried in hot sand, to allow of very gradual cooling and thus give every chance for the formation of crystals, in this way it was found possible to extend the cooling over from fourteen to eighteen hours.



During the heating the melted metal becomes thoroughly saturated with the carbon, which again crystallises out on cooling. On opening the crucible the metal is found in a single lump towards the bottom, and still surrounded by the undissolved carbon, from which it comes away quite easily and cleanly, and only requires to be washed with water and a small brush to remove the adhering carbon, when it is ready for extracting the crystallised carbon from its interior. On examining the metal at this stage of the operation, marked lines of crystallisation can be distinctly seen crossing the silver in two directions at right angles to one another.

The metal is now dissolved in nitric acid, when we obtain the dissolved carbon from its interior in the form of a greyish black powder possessing a beautiful graphitic lustre. On examining this powder under the microscope we find it to consist of three different kinds of substances—first of graphite, which forms the larger proportion; secondly of a number of small crystalline bodies of

octahedral form, also present in a fairly large quantity; and thirdly a quantity of a brownish substance probably amorphous carbon or a carbide of silver, which occurs in little flocks. It would appear from this that dissolved carbon, on crystallising slowly, takes the graphitic form in the hexagonal system in preference to the octahedral form of the diamond. I judge this from the fact of its occurring in so much larger a quantity. By washing this mixed powder by decantation, and then treating it first with hydrofluoric acid and then with ammonia, and further with caustic potash, the greater portion of the brown flocculent substance is thus got rid of, leaving the graphitic and adamantine carbon behind, and thus much more easy to examine.

These crystals then are found after the above treatment to have the following properties, viz. :—

1. They are unacted upon by ordinary acids and alkalies.
2. They remain unattacked even after boiling with hydrofluoric acid and being treated with it for some days, (these crystals were left under hydrofluoric acid from Friday morning until Monday morning).
3. They are extremely hard, and scratch glass and quartz quite easily, and I believe also the saphire; but being so minute it is not possible at present to speak absolutely on this point, though I am under the impression that scratches were certainly made.
4. When heated in a platinum crucible before the blowpipe, under a stream of oxygen they quickly glowed away.

Such are the properties of this powder.

It has already been stated that the larger proportion of the powder consisted of graphite, and of this it is not necessary to say more here; but to turn again to the other crystals, on making a closer examination under the microscope we find them to consist of two different kinds, some being dark-coloured whilst others are perfectly transparent; we will examine each of these two kinds of crystals separately.

First, the dark-coloured crystals, which are in most cases black, have a perfect octahedral form with curved edges, or in other words have the crystalline form peculiar to the diamond, and to that

substance alone. These crystals I believe to be true diamonds, which are coloured black by amorphous carbon being disseminated through them; indeed, a number of them are not entirely dark-coloured but transmit light, although not sufficiently to admit of their action on polarised light being given. To account for their being coloured in this way, it may be conceived to have occurred in the following manner, as far as the present experiments show:—

The metal on being fused and kept at a temperature considerably above its melting-point, and thus very liquid, dissolves the amorphous carbon until it becomes a perfectly saturated solution. In this state it can take up no more carbon, but there being a large excess of that substance in the impalpable amorphous state present, it becomes disseminated throughout this liquid mass, and when the latter crystallises the amorphous carbon is naturally enclosed in the crystals both of carbon and silver, and thus colours the former. This is also the source from which the amorphous carbon comes that as before-mentioned occurs stuck together in little flocks, along with these crystals, on dissolving the metal, only that of course it was enclosed in the crystals of the metal. This is so perfectly evident that it is unnecessary to say more about it here.

The question to be decided, then, is as to whether these dark crystals are really diamonds? If we consider their method of preparation from pure sugar charcoal, in charcoal crucibles, with pure metal, we see that the only substances they can possibly be are carbon, silver, or platinum (when an alloy of silver and platinum is used). I have not been able to detect the presence of either of the latter substances in them, and consequently believe them to be pure carbon. Moreover, their crystalline form, the perfect octahedra with *curved* edges, is the form of crystal peculiar to the diamond and to it alone, which makes one the more certain that these crystals are real diamonds though coloured. Again, the presence of graphite makes it more probable, and shows that the carbon must have been in such a state of molecular disaggregation as to allow it to pass from the amorphous form to the crystalline condition, and if so, why should it not take the diamond form as well as the graphitic one? which is in fact what has actually taken place. Although, as I have remarked above, the tendency is for the greater portion of this dissolved carbon to crystallise in the hexagonal or graphitic

form when cooling is extended over a long time, probably because working under some to us at present unknown law, it is easier for it to crystallise in that form than in the octahedral or cubical one. This might indeed form a subject for a very interesting research, "Whether any preference is shown by a body crystallising in two forms, to crystallise in one of the forms rather than in that of the other, and under what conditions it takes place to most advantage?"

From what has been said there can now be but little doubt as to whether these crystals are diamonds or not—that in point of fact they certainly are—and the questions now naturally arise as to whether they can be made of sufficient size to be of any practical use or value? if so, at what cost? and finally, whether they can be produced on a large scale without colour and with the lustre of the natural gem, so as to be available for ornamental purposes?

With regard to the first of these questions, Whether they can be made of sufficient size to be of any practical use? It is impossible at present to answer this question, these experiments having been made with only very small quantities of metal (in no case exceeding more than ten ounces), so that it can hardly be said that they have had given them a fair chance. I believe that if experiments were made with large quantities, say with 200 or 300 ounces of metal, one might obtain large crystals which, if even they were coloured, might be of immense value for drills and mining instruments, &c.

Then as regards the cost of production, that would be very slight, indeed only the cost of producing the sugar charcoal in an impalpable powder, as the silver (and platinum in case of an alloy) is all regained from its solution with very trifling loss, so that if the process on a large scale were to be a success, with practice it might be worked with but small expense. The third question as to whether they can be produced transparent and with the lustre of the natural diamond on a large scale is one purely of experiment. I am under the impression that this could be done as soon as one had learnt by practice just the amount of carbon necessary for the complete saturation of the metal and no more—it is probable that then these crystals might be obtained in a perfectly transparent condition possessing adamantine lustre—but after all it is a matter of experiment, and even though they were not produced of this kind so as to be serviceable for ornamental purposes, still if these

"carbonado" diamonds can be produced of sufficient size they will be of immense value.

The greatest advantage of this method of production is its simplicity, there being no difficulty about it, and absolutely no danger. It is exceedingly economical, in point of fact everything that could be desired, there being no useless bye-products formed, as everything can be reclaimed and used over again.

At the time that the preliminary experiment of this research was made, Dr Morrison and I were working together on the solubility of boron in silver, and after the success attending our experiments with boron we were led to try an experiment with carbon also; indeed the original idea with which we started on the research was to try the solubility of the three substances—carbon, boron, and silicon—in the different fused metals. Our first experiment with carbon was most successful, and at the end of our paper on the "Preparation and Properties of Pure Graphitoid and Adamantine Boron," * we made the following statement:—"The success of the boron experiments led us to try with carbon also, and the results have quite equalled our expectations. We are at present engaged with these experiments, and hope at some future time to lay the results before the Society." I quote this paragraph to show that as far back as June 17, 1878, when that paper was read, we had produced these bodies and felt justified in making the statement that we had done so, and intimated our method. At this stage of our joint operations we obtained a grant of £20 from the research fund of the Royal Society of London to enable us to continue the research. This we were unable to do jointly, on account of Dr Morrison's other engagements, and so he finally handed it over to me alone, grant and all complete, to work out by myself. The result has been that after eight months continuous work at it, and the performance of very many experiments, I am now able to lay these results before the Society. I think it right to say, that although after our first experiment Dr Morrison and I felt justified in making the statement above quoted, still I do not pretend to say that we were in a position to make any absolute statement about our results.

Secondly, on examining the transparent crystals, these are found to possess a beautiful adamantine lustre and high refractive and dis-

* Transactions of the Royal Society of Edinburgh, vol. xxviii. p. 689.

persive power, so as to be easily visible even when mounted in Canada balsam. They appear to be of octahedral form, but so far none of them seem to possess curved edges like the dark ones. Unlike the diamond they have a small action upon polarised light; this might, however, be caused by their too rapid cooling. What these crystals are I cannot at present say.

Finally, let me now call attention to the accompanying sketches which I have prepared to show the colour and perfect crystalline form of these different crystals:—

No. 1 is a crystal of very perfect octahedral form with curved edges, it is almost black, and is magnified about 520 diameters.

No. 2 is another crystal of the same form but not quite so dark in colour, being more brown; it is magnified to the same amount as the first one.

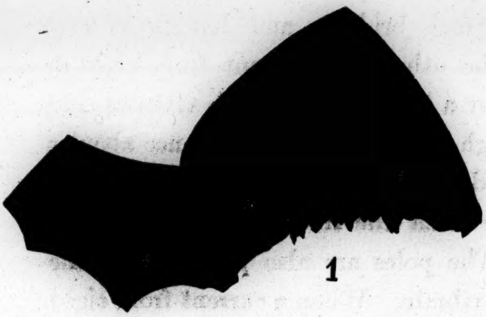
No. 5 is another of the same, only in this crystal the third edge can be distinctly seen.

No. 4 is a crystal of perfect octahedral form but without the curved edges; it is also magnified as the others.

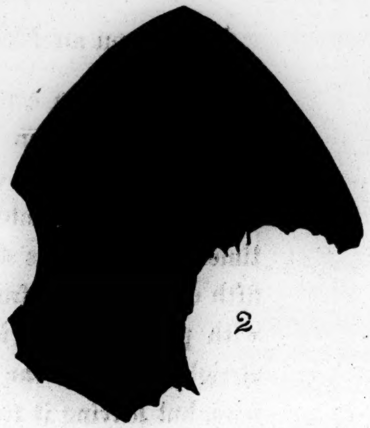
No. 3 is a fragment of a crystal which exhibits a number of scratches in its surface, most likely caused by the curved edged crystals rubbing against it. It is magnified some 78 times. The scratches were seen by reflected light.

No. 6 is a sketch of one of the transparent octahedral crystals as already described, and shows its perfect crystalline form and truncated corners; it is magnified some 520 diameters. It was mounted in Canada balsam, but its high refractive power rendered it easily visible. It had a slight action on polarised light.

In conclusion, I may state that a friend who has to deal with large quantities of gold and silver has kindly offered me the opportunity for making experiments on a large scale with 300, 400, or 500 ounces of metal at a time, so this method of production will shortly be put to a practical test. On the completion of these experiments I will bring any further results before the Society.

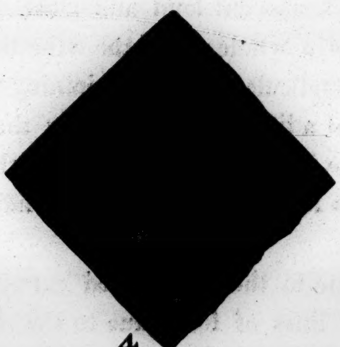


1

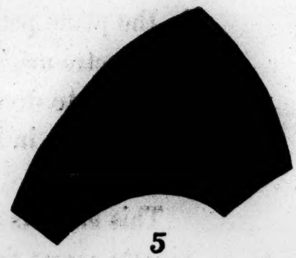


2

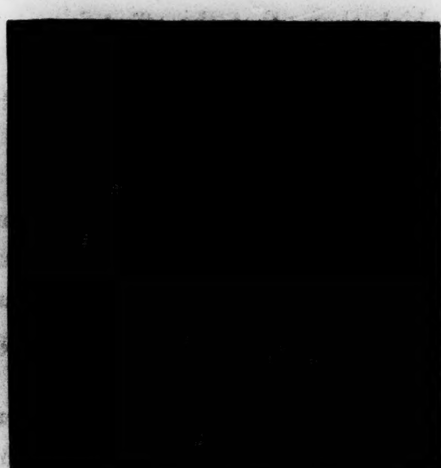
3



4



5



6

4. Note on an Electric Sonometer. By Prof. James Blyth.

The apparatus consists of an ordinary sonometer with five feet clear space between the two end bridges, and having a wire stretched from one end to the other. A current from eight or ten Grove's cells, interrupted by a tuning fork which vibrates 128 times per second, is sent through the wire. At a distance about a fifth of its length from the end of the wire a large electro-magnet, with pointed poles, is placed so that the line joining the poles is at right angles to the wires. The poles are also put close to the wire, but leaving it freedom to vibrate. When a current from eight Grove's cells is sent through the coils of the electro-magnet, the wire begins to sound, and by altering its tension the fundamental note of the wire comes out loud and clear. The wire is also seen to be vibrating as a whole; and the vibrations are also seen to be in the plane perpendicular to the line joining the poles. By shifting the electro-magnet a little, and regulating the tension of the wire, it is seen to divide into nodes and loops with one, with two, with three nodes in its length, thus giving the harmonics of the fundamental note.

This effect is due to the interrupted current causing the wire to vibrate across the lines of force due to the electro-magnet; in fact, the magnet appears very much to perform the function of the bow when employed to agitate the wire in the ordinary way.

I have tried different wires—iron, steel, and copper—all with the same result, which shows that the effect is not confined to wires formed of the magnetic metals alone.

This experiment helps to explain the action of the wire telephone, and shows that it is due mainly, if not entirely, to the transverse and not to the longitudinal vibrations of the wire.

By damping the wire at the requisite points along its length, the various notes of the scale can be distinctly reproduced.

All the notes produced are remarkably clear and beautiful, and the effect of a slight alteration of tension in altering the tone is very marked.

It is easy to see how an apparatus on this principle could be constructed for repeating Helmholtz's experiments on the vowel sounds.

5. Theory to account for certain movements exhibited by low forms of Animal Life, and termed Amœboid. By John B. Haycraft, Senior Demonstrator of Physiology in the University of Edinburgh.

A large number of unicellular plants and animals, and many of the cellular units which make up the complex tissues of man and more evolved animals, exhibit certain movements. These are termed "Amœboid," as they are well seen, and were at an early period studied in the Amœba.

If an amœba or a white blood corpuscle of the newt be examined with a good lens, the following facts, among others, may be made out. The corpuscle looks like a granular lump of jelly containing two or three nuclei, and it is, we will suppose, spherical to begin with. Soon the shape changes, for a little process is seen to protrude at one side, which may become retracted, or go on elongating. In the substance of the cell and in the processes, movements may be observed, consisting evidently of a flowing of the protoplasm, as indicated by the embedded granules which are carried along. The little processes are termed pseudopodia, and vary much in shape, some being thick and either pointed or club-shaped, others are filamentous, as in the perforated Foraminiferæ, where large numbers of these are seen radiating from the test. These movements may be automatic, and they are modified by various external forces; for example, heat and electricity.

I shall now endeavour to account for the throwing out and subsequent retraction of these little pseudopodia, pointing out, it may be, but one factor, but that a probable one.

Various theories have been already advanced (Brüeke, Hermann, Engelmann), which, for want of a better name, we may call geometrical: they would account well enough for the protrusion of processes had we the slightest evidence to suppose the imagined structures to exist.

The simplest of these supposes that, if at a certain spot on the surface of the cell a pseudopodium is to be protruded, contraction occurs along a chord of the segment, including this spot. Such a contraction could no doubt produce a protrusion, but it is gratuitous

to suppose that these creatures can extemporise chords of contractile tissue at will, and it explains in no way the subsequent retraction of the process.

Within the last ten years, histologists, working at the ultimate structure of the cell, have brought to light facts which may bear upon this point,—facts in morphology the functional significance of which is not yet clearly known.

Flemming, Strassburger, Klein, and others, have shown that "protoplasm" consists of two parts,—(1) a network or stroma, and (2) an interstromal matter filling up the meshes of the stroma. All cells which have as yet been examined show these two parts both in the mass of the cell and in the nucleus. This stroma is an anatomical whole, although no doubt subject to slow changes during growth and division, as is the cell itself. In various cell-units the arrangement differs somewhat, but these general points may be alluded to.

The stroma is a closed meshwork (not a stellate arrangement of particles), the tissue of which it is composed joining and anastomosing often, and at short intervals. The stroma is in connection with the nuclear wall, and with that of the cell if it be present.

Now, in many cells this network has a distinct mechanical function. In the ciliated cell, as Klein believes, the stroma is the mechanism productive of the movements of the cilia. In involuntary non-striped muscular fibres the fibrils are homologues of the stroma, although they do not anastomose, being arranged in parallel series. The same holds good for the voluntary striped fibre, where the fibrillæ representing the stroma (the cement is the homologue of the interstromal substance) perform the important function characteristic of the tissue—namely, contraction. It is seen then that in many cells the *stroma has a mechanical action possessing the power of contractility*, which, however, is not the case with the interstromal matter.

In those corpuscles which exhibit amœboid movements, may not these be due to some contractions of the stroma which they, in common with other cells, possess?

I may mention here that movements of the stroma of the white

corpuscles have been observed (Stricke); and in cell division, which is always associated with very slow change of shape or movement, the stroma certainly alters in a very marked manner (Flemming, Klein).

It may at first sight be thought that a pseudopodium is produced by a change (either of shortening or elongation) of part or the whole of the stroma, whereby a part of it protrudes as a process. This may be the case, but there are certain difficulties in accepting this view. The stroma is a closed network, and therefore the meshes must be broken up in order to allow of a portion of it at the surface to be separated from the rest in the form of a process; the superficial parts must be, in fact, torn away from those subjacent. Besides this, the substance of the pseudopodium is more fluid than that of the cell mass, looking in general very hyaline and uniform, although in some cases granules may be observed in its substance. The pseudopodia, moreover, are often very fine, quite as fine in fact as a strand of the meshwork itself.

Although no doubt a cell can change very considerably in form, due to the contractility of the stroma, the relations between the stroma and interstromal matter being inconsiderably altered, yet probably many at least of the pseudopodia, for the reasons given above, are formed in another way. They consist probably of the interstromal matter, or portions of it, projected outwards by the contractions of the stroma, which I imagine to occur in the following manner:—The stroma contracts at every part except where the pseudopodium springs from, forcing the interstromal matter at this point through the aperture left patent.

This accords well with the fact that the pseudopodia seem actually to be projected always as radia from the cell, and that they are of a very hyaline nature. The difficulty is to comprehend the forces engaged in their retraction. There are probably at least three, —(1) the relaxation of the stroma; (2) the viscosity of the substance, and (3) surface tension, in virtue of which a body tends to assume the spherical shape.

Now this may be very well theoretically, but are these three factors equal to the occasion is the question before us? I have imitated the structure of the amœba in the following way:—

An india-rubber ball is pierced by two or three holes near together; these should be about the diameter of a common darning needle. A larger aperture (half-an-inch across) is then made in the ball, but opposite to the smaller holes, and the ball half-filled with white of egg (unboiled) tinted with magenta. The ball represents the stroma, while the white of egg takes the place of the inter-stromal matter. The ball is now dipped into a beaker of water to which sugar has been previously added, until its specific gravity is equal to that of white of egg. Place a finger over the aperture through which the ball was filled, and press upon it with the other fingers of the same hand. Beautiful little magenta-stained pseudopodia will be projected from the small apertures into the sugar solution, and on relaxing the pressure, still keeping the finger over the aperture above, the pseudopodia will be completely retracted. I have been able in this way to project them three or four inches, and afterwards they have been completely retracted (the experiment was thus successfully performed in the Society's rooms).

One might use common water in place of the sugar solution, but as the specific gravity of the white of egg is greater than that of the water, the pseudopodia, when they have been projected more than an inch or so, break off and fall to the bottom. The size of the aperture is also rather a nice point, for there is one size—roughly $\frac{1}{16}$th inch in diameter—which is best suited for the white of egg, although any sized aperture will answer, though not so well. This no doubt varies with the fluid used;—ordinary ink may be substituted for the white of egg, and oil for the sugar solution.

I cannot but believe, that in the stroma the active cause for these movements is to be sought for, and, as far as I can see, it must act in one or other of the two ways described above, of which I think the last is least in antagonism to known facts.

While, no doubt, many of the bulgings seen in the white corpuscle of the newt's blood are due to changes in shape of the whole cell, probably with slight local accumulation of interstromal matter; yet may it not be that many of those fine hyaline processes are but interstromal matter projected from the cell?

There are, of course, many other phenomena exhibited by these cells, which I do not attempt to explain. For instance, there are stream movements seen in the cell, and even in the pseudopodia themselves. These are probably purely molecular, and may be the result of heat; for many curious movements and currents are to be observed in heating liquids, and especially a mixture of dissimilar ones.

If oil suspended in water, or acetic acid on a glass slide, be heated, as certain temperatures are reached flowing movements of a very curious nature are to be observed not unlike the streaming of protoplasm. This explanation has received a wider extension by Professor Rindfleisch ("Centralblatt," Oct. 23, 1880), who would account for much more upon this one factor.

That the above views are merely speculative, and views which may have eventually to be withdrawn, I need hardly say. It is natural and right to ask, when a new anatomical structure is discovered, What are its functions?

The paper of Professor Rindfleisch was not in my possession when I introduced this subject to the Society. I have taken, however, the liberty of mentioning its main contents.

Monday, 3d January 1880.

Professor DOUGLAS MACLAGAN, M.D., Vice-President, in the Chair.

The following Communications were read:—

1. On the Effect of Permanent Elongation on the Specific Resistance of Wires. By Mr T. Gray. Communicated by Sir William Thomson.

2. Meconic Acid. By Mr D. B. Dott. Communicated by Professor Crum Brown.

Although meconic acid is constantly taken, even in the most recent handbooks of chemistry, as an instance of a tribasic acid, it is

by no means certain that it possesses that nature. Some years ago, Dittmar and Dewar* investigated the matter, and came to the conclusion that meconic acid is dibasic though triatomic; but their experiments are not supposed to completely elucidate the subject. All published statements regarding this acid are consistent with it being only dibasic, if we except one or two analyses of its metallic salts. Only two ethyl ethers are known, while hydromeconic acid, which is formed from meconic acid by the action of sodium-amalgam, forms dibasic salts alone. With morphia and with aniline tribasic compounds are not known, though the dibasic salts are easily prepared.

There can be no doubt that the chief reasons for assuming the tribasic nature of meconic acid, are the statements which have been made concerning the composition and properties of the silver and lead salts, notably of the former. The object of the present paper is to prove that the alleged facts regarding these compounds do not rest upon solid ground.

The meconic acid used in the experiments hereafter described was carefully purified, being obtained in the form of well-defined prisms perfectly free from colour. No impurities for which it was tested were found to be present, and the acid neutralized the required proportion of standard alkali.

I. *Meconates of Lead.*

(1.) Prepared by adding solution of lead acetate in excess to aqueous solution of meconic acid. Even after long-continued washing the precipitate still yielded to the filtrate lead and meconic acid, showing that the salt is not insoluble, as is sometimes stated. After drying at 120° C. the meconate was ignited, and the residue ignited with ammonic nitrate to oxidize the metal.

8·295	grs. gave	4·22	grs. PbO	= 50·87	per cent.
8·260	„	4.20	„	= 50·84	„

(2.) This salt was prepared in the same way as the above, at least there was no difference noticed in the method of procedure.

47·50 grs. gave 26·70 grs. PbO = 56·21 per cent.

* Proc. Roy. Soc. Edin. 1867.

(3.) Another salt similarly prepared.

20·11 grs. gave 12·06 grs. = 59·96 per cent.

(4.) In this case the precipitate was produced by mixing solutions of lead acetate and neutral ammonium meconate

22·60 grs. gave 14·64 grs. PbO = 64·77 per cent.

(5.) This salt was prepared by adding solution of lead acetate to solution of neutral morphia meconate.

6·69 grs. gave 4·07 grs. PbO = 60·76 per cent.
$PbC_7H_2O_7$ = 55·06 per cent. PbO.
$(PbC_7H_2O_7)_2PbO$ = 64·76 per cent. PbO.
$Pb_3(C_7HO_7)_2$ = 65·91 „ „
$PbC_7H_2O_7PbO$ = 71·01 „ „

From these results it is manifest that the precipitates obtained as above described are of variable composition, and are probably mixtures of different salts. Stenhouse* prepared several basic salts, one of them containing as much as 64·7 per cent. of lead oxide. I believe it is this tendency of meconic acid to form basic salts, which has led to the belief in its tribraicity.

II. *Meconates of Silver*

(1.) Prepared by adding nitrate of silver in excess to solution of neutral ammonium meconate. Precipitate dried at 100° C.

9·82	grs. gave	3·44	grs. Ag	= 35·03	per cent.
12·77	„	4·47	„	= 35·00	„

(2.) This precipitate was produced by adding excess of silver nitrate to alkaline solution of ammonium meconate, the product being dried at 120° C.

10·050	grs. gave	4·86	grs. Ag	= 48·35	per cent.
9·745	„	4·72	„	= 48·38	„

(4.) Prepared by mixing solutions of ammonium meconate and silver nitrate, the former being in excess. Precipitate dried at 100° C.

10·215	grs. gave	5·195	grs. Ag	= 50·85	per cent.
9·310	„	4·705	„	= 50·53	„

* Gmelin's Handbook, xii. 428.

(5.) Prepared by mixing solutions of meconic acid and nitrate of silver, the resulting precipitate being dried at 120° C.

6·46 grs. gave 3·42 grs. Ag = 52·94 per cent.

(6.) Prepared by adding argentic nitrate to solution of neutral meconate of ammonia. Dried at 120° C.

8·035 grs. gave 3·385 grs. Ag = 42·12 per cent.

(7.) Prepared in the same way as the preceding.

12·410 grs. gave 5·705 grs. Ag = 45·97 per cent.

(8.) Prepared by mixing solutions of silver nitrate and neutral morphia meconate. Precipitate dried at 120° C.

6·11 grs. gave 3·41 grs. Ag = 55·81 per cent.

(9.) A quantity of argentic meconate prepared by precipitation was boiled for a few hours with water, the residue then dried and ignited.

6·075 grs. gave 3·785 grs. Ag = 56·45 per cent.

(10.) Another portion of the same salt was boiled in water for twenty-four hours.

2·840 grs. gave 1·725 grs. Ag = 60·73 per cent.

(11.) Another portion boiled for forty hours, and the residue similarly ignited.

6·065 grs. gave 5·390 grs. Ag = 88·87 per cent.

(12.) A quantity of argentic meconate, formed by mixing solutions of nitrate of silver and meconate of ammonia, was boiled with water for forty hours and the resultant substance ignited.

3·67 grs. gave 2·84 grs. Ag = 77·38 per cent.
$AgC_7H_3O_7$ = 35·17 Ag per cent.
$Ag_2C_7H_2O_7$ = 52·17 „
$Ag_3C_7HO_7$ = 62·18 „

When the experimental results above described are compared with the numbers just given, it will be noticed that in no case do

the figures correspond, while in Nos. 11 and 12 the percentage of silver is far above that required for the triargentic salt. Wackenroder* appears to have been the first to afford the information that a tribasic meconate of silver is produced by precipitation, when the ammonium meconate is used, and that the same salt is formed by boiling the diargentic meconate with water. These statements, though generally accepted as correct, are not borne out by anything I have observed. Doubtless, if in boiling the meconate of silver with water the operation be stopped at a certain point, the product will have apparently the composition of the triargentic salt; but then, if the boiling be continued, the percentage of silver increases, until probably there is nothing but oxide of silver left. There is therefore no evidence that a tribasic meconate has been prepared, and we are not, so far as I can see, in possession of any information which should lead us to suppose that meconic acid is tribasic.

3. On the Crystallization of Silica from Fused Metals. By R. Sydney Marsden, D.Sc., F.R.S.E., F. Inst. Chem., &c.

The crystallization of silica from fused metals, although at first sight appearing to be of little importance, nevertheless presents some features of peculiar interest. It also constitutes a field almost entirely new to the investigator, though the subject is one which, from a technical point of view, may prove to be of very considerable importance.

I have therefore undertaken the examination of some of the facts relating to this subject—at first more particularly inquiring into the nature of the change which occurs when silica itself is kept at a high temperature for a number of hours and subsequently submitted to a process of very slow cooling.

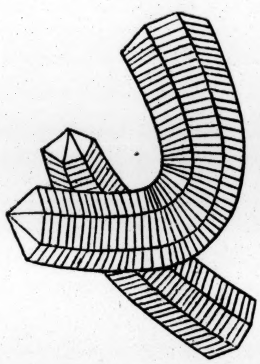
The substance which formed the basis of these operations, and in which the changes hereafter mentioned were noticed, consisted of several Berlin porcelain crucibles, in which, in the course of some other experiments, I had reason to keep metallic silver and amorphous carbon at a temperature considerably above the melting point of the former, for a number of hours, and subsequently

* Gmelin's Handbook, xii. 430.

submit them to a cooling process extending over some twelve or fourteen hours.

Whilst pursuing the other experiments, on dissolving the silver afterwards in nitric acid, it yielded from its interior a number of very beautiful laminæ or leaf-shaped crystals of the hexagonal system, and varying in colour from light yellow to dark brown or even black, which at first sight I mistook for graphite, formed by the solution of the carbon in the silver and crystallizing out from it in this characteristic form.

There were also present a number of other crystals in the form of hexagonal prisms or crystalline aggregates, but these were in many, if not in all cases, perfectly colourless and transparent. It may be mentioned that some of them appeared to possess the curved form sometimes met with in quartz, and given in fig A.



Neither hydrochloric acid nor nitric acid had any action upon them, but on treating them with boiling hydrofluoric acid for some time, they quietly dissolved, and the same thing occurred when they were boiled with a strong solution of caustic potash.

This perplexed me at first with regard to the leaf-like forms, for it was perfectly clear that they were not graphite, and I could not find that silica was known to crystallize in that manner. It was evident the silver must therefore have been in contact with the porcelain crucible, and these crystals in this way derived from it.

The thing to be done then was to have some microscopic sections made of the different crucibles,—first of one which had not been heated, and then of those which had been used in the experiments in order to see what effect the heat had had upon them. In this way it was possible to compare the two side by side, and what I found was this, that the alumina portion of the crucible had undergone little or no change, but that the glaze of the crucible, consisting of silica, which, in the original condition, was in a perfectly homogeneous and vitreous state after the heating, had become one mass of little crystals in the form of hexagonal prisms. Here then was a clue to what these unknown crystals were, namely, silica.

The prismatic crystals were evidently derived from this source, and simply occurred diffused through the silver by having been taken in through the action of convection currents, which still operated—after they had been produced through the cooling of the silica to the temperature necessary for their formation—whilst the silver yet remained in a perfectly liquid condition.

The leaf-like crystals, it was easily to be conceived, were from the same source; but the question naturally arises, as to what led the portion of the silica of which they were composed to crystallize in this peculiar graphite-like form instead of in its usual prismatic one, as it had done in the glaze of the crucible, where it had not been in contact with the metal?

To account for this, it is conceivable that here we had silica in quite a different state from what it is when heated by itself—namely, in a state of *solution*, in the silver (not suspension), and that in this condition of solution it is capable of undergoing what we may designate as a molecular disaggregation, owing perhaps to some influence of the silver, and thus to be capable of arranging itself in these new forms.

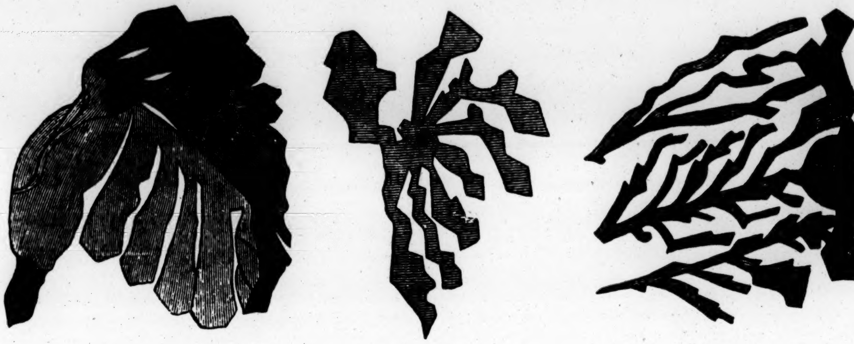
At first I thought that possibly these crystals might be composed of silicide of silver, for it is stated ("Watts's Dictionary," vol. v. p. 241) that "silica is decomposed by carbon in the presence of silver at a white heat, carbonic acid and a silicide of silver being formed."

Be this as it may, these experiments do not appear to confirm this statement; for although they were conducted at a temperature a little above the melting point of steel, yet, on testing the solution of these crystals for silver, it was not possible to detect the slightest trace of that metal.

Their colour I believe to be due either to amorphous-carbon in a state of extremely minute division being disseminated through them, or perhaps to the presence of a very slight trace of iron which might be derived from the other part of the crucible. Accompanying this paper are some sketches showing the beautiful form and colour of several of these crystals, and in which they are enlarged about 320 diameters.

A study of the crystallization of silica from iron, and the effects which it produces in so doing, seems likely to yield some results of

a most interesting nature. While the subject of the solution of different bodies in fused metals, although up to the present time it



appears to have been almost entirely neglected, will also probably yield a rich harvest, and explain to us many things which are at present but imperfectly understood.

The further development of this research is in progress.

4. On Phosphorus Betaines. By Professor E. A. Letts.

(*Abstract.*)

The experiments of Professor Crum Brown and the author on the "Thetines" and their derivatives* have clearly shown that very striking analogies exist between certain compounds of nitrogen and sulphur. Thus sulphide of methyl closely resembles trimethylamine (and ammonia), in many of its reactions, and in the products which it gives rise to. Like trimethylamine it combines with a molecule of bromacetic acid, and the resulting product, which was named hydrobromate of dimethyl-thetine, behaves in certain respects like the compound of bromacetic acid and trimethylamine (hydrobromate of betaine).

Analogous phosphorus compounds have been obtained: in the ethyl series by Hofmann,† in the methyl series by A. H. Meyer.‡ The latter compound is simply the betaine salt in which the

* Trans. Roy. Soc. Ed. xxviii.

† A. W. Hofmann, "Proc. Roy. Soc. Lond." xi.

‡ A. H. Meyer, "Berichte d. deutsch. chem. Ges." iv. 734.

nitrogen is replaced by phosphorus, and may be called a salt either of *phosphorus-betaine* or of *trimethyl-phosphorus-betaine.* In the paper before alluded to by Professor Crum Brown and the author, the opinion was expressed that the compounds of thetine would probably show greater analogies with these bodies than with the compounds of betaine itself.

The author's experiments were undertaken with the view of testing the correctness of this opinion.

As the phosphorus betaines had only been subjected to a cursory examination by Hofmann and Meyer, it was deemed essential, in the first place, to prepare them in the pure state and in large quantities, and to determine their chief properties. This has been done, but has necessitated a large expenditure of time, owing to the difficulties experienced in preparing the material necessary for the research. The author's first experiments were made in the methyl series, but, owing to the difficulty he experienced in preparing the necessary trimethyl-phosphine, it was decided to operate in the ethyl series.

The triethyl-phosphine was prepared by Hofmann and Cahours' method, viz., by treating zinc ethyl with terchloride of phosphorus. This method the author has found to give excellent results, and recommends it as far more certain than the later process which Hofmann discovered, viz., heating alcohol to 180° with phosphonium iodide.

The earlier attempts which the author made to prepare the compounds of phosphorus betaine, were made with bromacetic acid and triethyl-phosphine, but without success. An interesting body was however obtained, which will be described in another communication.

Action of Chloracetic Acid on Triethyl-phosphine.—Triethyl-phosphine, when added cautiously to chloracetic acid, dissolves the latter, and on shaking the mixture a dense oily layer separates; much heat is evolved, and it is necessary to cool the vessel in which the operation is conducted by immersion in cold water. If the experiment is properly conducted, the oily liquid solidifies in about an hour to a mass of colourless crystals. This is easily soluble in alcohol, but is precipitated in long colourless needles by the cautious addition of ether to the hot solution.

The analysis of the body thus purified, and of its chloroplatinate, leaves no doubt as to its composition. It is the hydrochlorate of triethyl-phosphorus-betaine, $(C_8H_{17}PO_2)HCl$, formed by the direct union of one molecule of chloracetic acid with one of triethyl-phosphine

$$P(C_2H_5)_3 + Cl{-}CH_2{-}COOH = (C_2H_5)_3{\equiv}P\begin{smallmatrix}{-}CH_2{-}COOH\\{-}Cl\end{smallmatrix}.$$

Contrary to expectation and to Hofmann's statement, it is not perceptibly deliquescent, and may be exposed to the air for days without liquefying. It has a sour taste and acid reaction.

Its *chloroplatinate*, $(C_8H_{17}PO_2HCl)_2PtCl_4$, forms somewhat soluble crystals of a light orange colour, which may be obtained of large size.

The *sulphate*, $(C_8H_{17}PO_2)_2SO_4$, obtained by acting on the hydrochlorate with sulphate of silver and evaporating the solution *in vacuo*, forms a solid crystalline mass. It was not analysed owing to its deliquescence.

The *base*, $(C_8H_{17}PO_2)OH$, was obtained from the hydrochlorate by the action of oxide of silver and subsequent evaporation of the solution *in vacuo* It is crystalline but extremely deliquescent. Exposed for some months *in vacuo* over sulphuric acid, it loses a molecule of water, and is converted into the anhydrous base*

$$(C_2H_5)_3{\equiv}P\begin{smallmatrix}{-}CH_2{-}COOH\\{-}OH\end{smallmatrix} = H_2O + (C_2H_5)_3{\equiv}P\begin{smallmatrix}{-}CH_2{-}CO\\{-}O{-}\end{smallmatrix}$$

The anhydrous base was analysed.

Ethyl-chlorate of Triethyl-phosphorus-betaine. — According to Hofmann (*loc. cit.*) chloracetic ether combines with triethyl-phosphine with the evolution of heat, and formation of a brownish liquid of considerable consistency. On repeating this experiment the author obtained a colourless syrup which solidified after a few minutes to a colourless crystalline mass.

The ethyl-chlorate thus obtained is extremely deliquescent, and cannot be recrystallised.

Its composition was verified by the analysis of its platinum salt,

* The base dimethyl-thetine behaves in a similar manner.

which is easily obtained in light orange-coloured plates on mixing aqueous solutions of the ethyl-chlorate and chloride of platinum. It is somewhat soluble, and may be recrystallised from boiling water. Its composition is represented by the formula.

$$(C_8H_{17}PO_2 \cdot C_2H_5 \cdot Cl)_2PtCl_4$$

Action of Oxide of Silver on Ethyl-chlorate of Triethyl-phosphorus-betaine.—Hofmann states (*loc. cit.*) that the following reaction occurs when oxide of silver acts on the ethyl chlorate.

$$(C_2H_5)_3{\equiv}P{<}^{-CH_2-COOC_2H_5}_{-Cl} + AgOH =$$

$$(C_2H_5)_3{\equiv}P{<}^{-CH_2-CO}_{-O-} + C_2H_5OH + AgCl$$

The author finds that this statement is correct, but noticed that when the two bodies are mixed (in aqueous solution) a strong smell of acetic ether is developed. He thinks it probable that a second reaction occurs which may be represented thus—

$$(1.)\ (C_2H_5)_3{\equiv}P{<}^{CH_2-COOC_2H_5}_{-Cl} + AgOH =$$

$$(C_2H_5)_3{\equiv}P{<}^{-CH_2-COOC_2H_5}_{-OH} + AgCl$$

$$(2.)\ (C_2H_5)_3{\equiv}P{<}^{-CH_2-COOC_2H_5}_{-O\ H} = (C_2H_5)_3{\equiv}PO + H{-}CH_2COOC_2H_5$$

Ethyl-bromate and Ethyl-iodate of Triethyl-phosphorus-betaine were obtained by the direct union of bromacetic and iodacetic ether with triethyl-phosphine: they resemble the ethyl-chlorate in their properties and reactions.

Action of Heat on the compounds of Triethyl-phosphorus-betaine.—In his paper on the action of heat on the compounds of dimethyl-thetine* the author showed that the latter experience two kinds of decomposition when heated: the *haloid* salts yield thio-diglycollic acid and a compound of trimethyl-sulphine, whilst the *oxy* salts split up into carbonic anhydride and a salt of trimethyl-sulphine.

* Trans. Roy. Soc. Edin. vol. xxviii.

Thus the hydrochlorate and hydrate decompose in the following manner:—

$$(1.)\ 2\left[(CH_3)_2 \equiv S \begin{matrix} -CH_2-COOH \\ -Cl \end{matrix}\right] = (CH_3)_3SCl + S(CH_2-COOH)_2$$

$$(2.)\ (CH_3)_2 \equiv S \begin{matrix} -CH_2-COOH \\ -OH \end{matrix} = (CH_3)_3SOH + CO_2$$

The author has investigated the action of heat on the compounds of triethyl-phosphorus-betaine to ascertain whether they would behave like the thetine compounds.

Action of Heat on Ethyl-bromate of Triethyl-phosphorus-betaine.—The ethyl-bromate, when heated, fuses, effervesces, grows brown, and solidifies after some time. When this has occurred but little more gas is evolved. The solid product may be crystallised from chloroform, and its analysis shows that it is the bromide of triethyl-methyl-phosphonium $(C_2H_5)_3(CH_3)PBr$. The chloroplatinate obtained from it by the action of oxide of silver, and then of chloride of platinum on the filtered solution, crystallises in very characteristic orange-coloured octohedra with truncated edges. The formula

$$\left((C_2H_5)_3(CH_3)PCl\right)_2PtCl_4$$

was verified by analysis.

The gas evolved consists in large measure of carbonic anhydride. The *ethyl-chlorate* behaves, when heated, like the ethyl-bromate, yielding chloride of triethyl-methyl-phosphonium. The author carefully examined the gaseous products of the reaction, and found that they consisted mainly of carbonic anhydride and ethylene. The decomposition which the ethyl-chlorate suffers when heated, may be represented by the equation

$$(C_2H_5)_3 \equiv P \begin{matrix} -CH_2-COO\,C_2H_5 \\ -Cl \end{matrix} = (C_2H_5)_3 \equiv P \begin{matrix} -CH_3 \\ -Cl \end{matrix} + CO_2 + C_2H_4$$

and that of the ethyl-bromate in a similar manner.

Action of Heat on Hydrochlorate of Triethyl-phosphorus-betaine.—The action of heat on the hydrochlorate is much more definite than in the case of the bodies just mentioned. The hydrochlorate, when

heated, fuses, effervesces, and suddenly solidifies, giving a pure white product. The gas evolved consists of pure carbonic anhydride. The decomposition occurs quantitatively according to the equation

$$(C_2H_5)_3{\equiv}P{<}^{-CH_2}_{-Cl}\ \vdots\ COO\vdots H = (C_2H_5)_3{\equiv}P{<}^{-CH_3}_{-Cl} + CO_2$$

The composition of the phosphonium salt was verified by the characteristic crystalline form, and by the analysis of its chloroplatinate.

Action of Heat on Sulphate of Triethyl-phosphorus-betaine.—The sulphate behaves, when heated, in the same manner as the hydrochlorate, the products of its decomposition consisting of carbonic anhydride and sulphate of triethyl-methyl-phosphonium.

Action of Heat on the Base Triethyl-phosphorus-betaine.—The decomposition which the base suffers when heated is very interesting.

When preparing the base it was noticed that, if its aqueous solution be concentrated by boiling, a faint odour of triethylphosphine is developed, and that when the concentrated solution is placed *in vacuo* it effervesces and eventually solidifies.

It now, when treated with acids (even tartaric acid), effervesces, and has a faint *acid* reaction. In fact, it behaves as a *bicarbonate*, and there can be little doubt that the base when heated, suffers an isomeric change — bicarbonate of triethyl-methyl-phosphonium resulting—

$$(C_2H_5)_3{\equiv}P{<}^{-CH_2-COOH}_{-OH} = (C_2H_5)_3{\equiv}P{<}^{-CH_3}_{-O-COOH}$$

The production of the phosphonium salt was proved by the analysis of the chloroplatinate, as well as by the characteristic crystalline form of the latter.

The experiments just described show that a close and interesting analogy exists between the compounds of phosphorus-betaine and of thetine.

This is the more interesting, as the same analogies do not exist between these two classes of compounds, and the corresponding nitrogen compound (betaine), the salts of the latter when heated

suffering dissociation into trimethylamine and a derivature of acetic acid, or simply volatilizing without change.

The predictions of Dr Crum Brown and the author have thus been verified.

5. On the Action of Haloid Compounds of Hydrocarbon Radicals on Phosphide of Sodium and on the Salts of Tetra-Benzyl-Phosphonium. By Professor Letts and N. Collie, Esq.

(*Abstract.*)

The difficulty of preparing tertiary phosphines either by heating alcohols with phosphonium iodide or by acting on zinc ethers with terchloride of phosphorus, of which we have had much experience, induced us to seek for other and less troublesome methods for obtaining these bodies in considerable quantity.

The ease with which phosphorus combines with certain metals, and the readiness with which the resulting compounds react on haloid ethers of hydrocarbon radicals led us to think that, if only comparatively pure metallic phosphides could be obtained by a simple process, we should have no difficulty in preparing the tertiary phosphines and phosphonium compounds.

This is no new notion,—all the earlier experiments* to obtain phosphines having been made by the action of metallic phosphides on the chlorides and iodides of hydrocarbon radicals. Hofmann employed sodium phosphide, but eventually gave up the method on account of the uncertainty of the reaction, the frequent explosions in operating on the phosphide of sodium, and the great difficulties experienced in separating the resulting phosphines from each other, "not to speak of the difficulty of obtaining the phosphide of sodium fit for the reaction."

In experiments which we have made with this method in the ethyl and benzyl series we have not experienced the difficulties of which Hofmann and others speak.

* Paul Thenard, "Compt. Rend.," xx. 144, and xxv. 892; Berlé, "Journ. für prak. Chem.," 66, 73; Cahours and Hofmann, "Compt. Rend.," xli. 818; Drechsel and Finkelstein, "Ber. deut. Chem. Ges.," iv. 352.

Our researches on the action of iodide of ethyl on phosphide of sodium are still proceeding, but those on the action of chloride of benzyl on the same body are sufficiently advanced to warrant us drawing attention to them.

The preparation of phosphide of sodium is accomplished without difficulty or danger by melting sodium in xylol and adding phosphorus in small pieces. It depends, however, entirely on the manner in which the phosphide is made, and on the proportions of phosphorus, sodium, chloride of benzyl and xylol taken as to the quantity and nature of the resulting phosphine compounds.

The chief product of the reaction is the chloride of tetra-benzyl-phosphonium, which is probably formed according to the equation

$$4\ C_7H_7Cl + Na_3P = 3\ NaCl + (C_7H_7)_4PCl,$$

but the quantity formed may in an ill conducted experiment be as low as 1 per cent. of the theoretical amount, whereas with proper proportions of the substances giving rise to it we have succeeded in obtaining over 40 per cent. with certainty.

The proportions and exact method of procedure we propose to give in another paper, contenting ourselves for the present by saying that it is possible to prepare 60 grammes of almost pure chloride of tetra-benzyl-phosphonium in about five hours. We believe that this result could not be obtained by either of the ordinary methods for preparing phosphines.

Hofmann* has investigated mono- and di-benzyl phosphine, but so far as we are aware tri-benzyl-phosphine and the salts of tetra-benzyl-phosphonium have not hitherto been obtained.

Chloride of tetra-benzyl-phosphonium, $(C_7H_7)_4PCl$, is dissolved out of the product of the action of chloride of benzyl on phosphide of sodium by boiling water and crystallises when the filtered aqueous solution cools in magnificent needles which may attain the length of an inch and a half.

By recrystallisation from boiling water it may be obtained colourless and pure. It contains water of crystallisation which it loses when heated. The dried compound melts at about 224°–

* Hofmann, "Ber. deut. Chem. Ges.," iv

225° C. (uncor.). Its composition was verified by determinations of carbon, hydrogen, and chlorine.

Chloroplatinate of tetra-benzyl-phosphonium, $2(C_7H_4)_4PCl,PtCl_4$.—Mixed with chloride of platinum the preceding body yields in alcoholic solution insoluble leaflets of a light orange colour, in aqueous solution a light yellow precipitate of the chloroplatinate of tetra-benzyl-phosphonium.

Its formula was verified by determination of its carbon and hydrogen.

The chloroplatinate is very slightly soluble in water and alcohol.

Acid sulphate of tetra-benzyl-phosphonium, $(C_7H_4)_4PHSO_4$.—Up to the present time the normal sulphate has not been obtained. The acid sulphate is formed either by treating a solution of the chloride with sulphate of silver, or warming the dry chloride with strong sulphuric acid. It is more soluble than the chloride, and separates in plates from a hot and somewhat concentrated aqueous solution.

Its analysis (carbon, hydrogen, and sulphuric acid) showed that it has the composition

$$(C_7H_7)_4PHSO_4$$

It is remarkable that the acid sulphate is obtained from the chloride and sulphate of silver instead of the normal sulphate.

Action of Caustic Baryta on Acid Sulphate of Tetra-Benzyl-Phosphonium.—The action which occurs when solutions of these two bodies are mixed, varies in a remarkable manner with the conditions of the experiment.

In our earliest attempt to prepare the hydrate of tetra-benzyl-posphonium by this reaction, we failed to obtain any body easily soluble in water as we expected the hydrate would be. On repeating the experiment we however obtained an easily soluble body which turned out to be the hydrate, but on attempting to prepare more of it we were again unsuccessful.

We found, however, that although no body soluble in water was formed, boiling alcohol took up from the precipitated sulphate of barium a considerable quantity of a substance which was deposited in crystals as the solution cooled.

Later experiments have shown us that the hydrate is only formed

when very dilute solutions of the acid sulphate and caustic baryta are taken, whilst on the other hand the insoluble body appears to be the only product when concentrated solutions are employed.

The analysis of the insoluble product led us to the very unexpected result that it was the oxide of tri-benzyl-phosphine. The formation of this body is only intelligible on the assumption that it arises from the breaking up of the hydrate, and that toluol is produced along with it—

$$(C_7H_7)_4POH = (C_7H_7)_3PO + C_7H_8 .$$

That this is the explanation of its formation was easily verified by mixing the solutions of the acid sulphate and caustic baryta in a distilling flask connected with a condenser, and boiling the mixture. An oily liquid passed over which was lighter than water, and had all the properties of toluol, and its amount agreed with the quantity demanded by theory. This reaction which we have described is perfectly anologous to the behaviour of tetrethyl phosphonium hydrate when heated*

$$(C_2H_5)_4POH = (C_2H_5)_3PO + C_2H_6 .$$

But we think it remarkable that the hydrate of tetra-benzyl phosphonium should break up so easily.

Hydrate of tetra-benzyl-phosphonium.—This body is obtained when boiling solutions of the acid sulphate and caustic baryta are mixed—provided as just stated the solutions be very dilute. It separates from the solution filtered off from the sulphate of barium, (formed at the same time) after considerable concentration, *which we always effected by boiling.*

The hydrate is very soluble, and crystallises easily in transparent tables of striking refractive power. Its composition was verified by determinations of hydrogen and carbon.

Like other soluble compounds of tetra-benzyl-phosphonium the hydrate, even in very dilute solutions, is precipitated by hydrochloric acid, the chloride resulting.

We are engaged in preparing other salts of tetra-benzyl-phosphonium, and in investigations on them, especially the action of

* Hofmann, "Phil. Trans.," 1857.

heat, which in one or two cases has already given interesting results.

We propose also to study the action of phosphide of sodium on other haloid derivatives—especially on chloride of phenyl.

6. Notice of an Easy Method for determining the Position of the Principal Focus of an Object-Glass. By Edward Sang.

Just as the past progress of astronomy has, in a great measure, been due to the improved construction of our instruments, so its future progress must depend much on the accurate confection of our telescopes, and most of all on the excellence of the object-glasses.

In the actual formation of a compound lens, after the thicknesses and curvatures have been fixed, we have to make the tools to the proper shapes and with those to grind and polish the glass. It is impossible, even with the greatest care, to bring the workmanship so close to the computations as that appreciable differences may not be found, and hence the finished lens hardly ever comes so near to our expectations as that it may not be necessary to test it by actual trial. One important matter to be so settled is the exact position of the principal focus, since that is needed for determining the length of the tube.

The obvious course of procedure is to place the lens in a temporary frame and to direct it to the sun, to a star, or to some very remote terrestrial object. This, however, requires clear air and open space such as is not always to be had in a large town. To bring the whole operation within the limits of the workshop I have had recourse to the following expedient:—

The lens, in its setting, is secured against the surface of a flat mirror or speculum, and is set up on a table of sufficient length. A well illuminated object is then placed approximately in the focal plane. The light from this object, after having passed through the lens is reflected from the mirror and again passes through the lens, being converged to form an inverted image.

If the object be placed within the focal distance, the image will

be formed beyond; the true focal distance for parallel rays being the harmonic mean between the two. Hence, if we modify the position until the object and its image coincide, we shall have the exact position of the principal focus; always, however, subject to the condition that the mirror be quite flat.

A convenient plan is to draw two strong lines crossing each other on a piece of stiff paper, repeating them exactly on the other side, and then to cut the paper in two through the centre of the cross; using only the one part. The exact completion of the half-cross by its image is a severe test of the adjustment, and the motion of the eye across the field at once detects any parallax. A hand eye-glass of say one inch in focal length should be used in the examination.

7. Note on the Temperature Changes due to Compression. By Professor Tait.

The author described the results of a number of experiments, made during the examination of the "Challenger" Deep-Sea Thermometers, with the view of testing, at pressures of 3 tons weight per square inch and upwards, Thomson's formula for the heat developed by compression (Proc. Roy. Soc., 1857, p. 568).

When, for instance, the bulb of one of the thermometers was surrounded by a shell of lard upwards of half an inch thick, the total effect produced by a pressure of $3\frac{1}{2}$ tons weight was 5° F.; while for the same pressure, without the lard, the effect was only 1°·8 F. The temperature of the water in the compression apparatus was 43° F., so that the temperature effect due to the compression of water was less than 0°·2 F. In obtaining this number it was assumed from Kopp's experiments that the coefficient of expansion of water at a temperature $t°$ C., near its maximum density point (roughly, 4° C.), is about $\frac{t-4}{72{,}000}$. Hence the effect due to the compression of the lard was 3°·4 F., or about 1° F. per ton weight. This is subject to corrections (which will *increase* its value) depending on the heat developed by friction in the pump and in the narrow connecting tubes, and on another cause not yet fully ascertained.

The author proposes to continue these experiments, at still higher pressures, with a modified apparatus, which will enable him to measure the temperature effects by means of a thermo-electric junction. The present process, with thermometers, is applicable only to liquids and to semi-liquid substances like lard.

BUSINESS.

Dr G. A. Gibson was balloted for, and declared duly elected a Fellow of the Society.

Monday, 17th January 1881.

PROFESSOR FLEEMING JENKIN, Vice-President, in the Chair.

The following Communications were read:—

1. Preliminary Report on the TUNICATA of the "Challenger" Expedition. Part III. By W. A. Herdman, D.Sc., F.L.S.

(*By permission of the Lords Commissioners of the Treasury.*)

III. CYNTHIADÆ.

This family includes two of Savigny's genera—*Boltenia* and *Cynthia*, and may be defined by their common characters if we omit or modify one point on which considerable stress is usually laid, namely, the number of lobes round the branchial and atrial apertures.

The amended definition of the family is as follows:—

Body attached, sessile or pedunculated; apertures four-lobed, or having less than four lobes.

Test coriaceous; rarely cartilaginous or gelatinous.

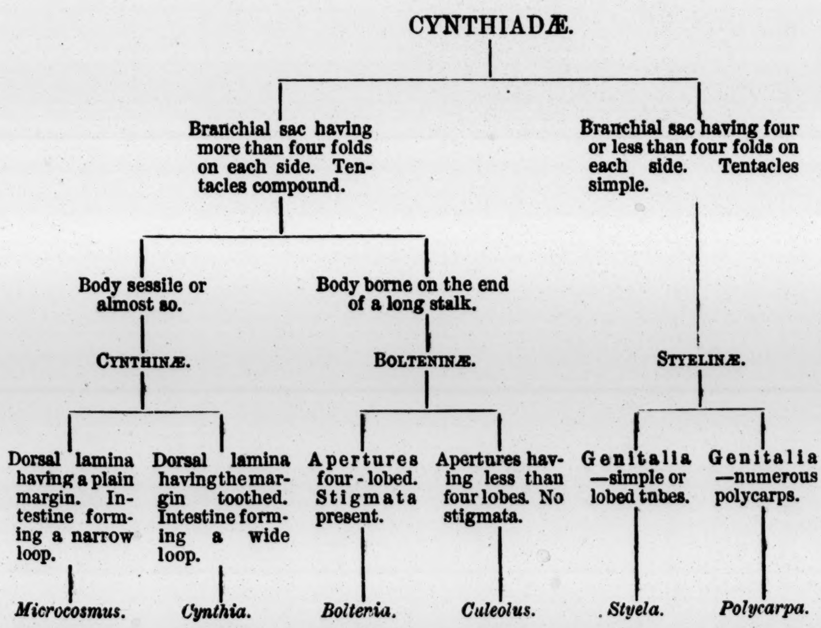
Branchial sac folded; internal longitudinal bars present, no papillæ; stigmata straight (rarely absent).

Tentacles simple or compound.

In the "Mémoires sur les animaux sans vertèbres," the genus *Cynthia* is broken up into four tribes, viz., *Cynthiæ Simplices*, *Cynthiæ Cæsiræ*, *Cynthiæ Stylæ*, and *Cynthiæ Pandociæ*. Of these the second contains only one species, *Cynthia dione*, which does not belong to this family but to the Molgulidæ. Another tribe, the *Cynthiæ Pandociæ*, containing three species, *Cynthia mytiligera*, *C. solearis*, and *C. cinerea*, was distinguished from the *Cynthiæ Stylæ* solely by the position of the ovary in the intestinal loop. R. Hertwig * has, however, shown that the body which Savigny took for the ovary is really merely a fold of the lining membrane. The *Cynthiæ Pandociæ* may therefore be merged in the *Cynthiæ Stylæ*. The remaining two of Savigny's tribes, the *Cynthiæ Simplices*, and *Cynthiæ Stylæ* are natural groups, and as it has been necessary to divide them both into genera, should be retained as subfamilies which may be called *Cynthinæ* and *Stylinæ*.

To these I add a third sub-family, the *Bolteninæ*, representing the old genus *Boltenia*, and including, in addition, a new genus, *Culeolus*, and probably also Macleay's *Cystingia*.

The following table shows the arrangement of the sub-families and genera of the Cynthiadæ.



* Jenaische Zeitschrift, Bd. viii. p. 96.

Microcosmus, Heller.

This genus is distinguished from *Cynthia*, according to Heller,* by the possession of a plain-edged dorsal lamina and a narrow intestinal loop; while in all species of *Cynthia* proper the dorsal lamina is denticulated on the free margin, and the intestine forms a wide loop.

It is undoubtedly convenient to separate the two groups of species, and they form very natural sections of *Cynthia;* but whether the denticulation of the dorsal lamina, and the amount of curvature in the intestine are sufficient characters for the formation of a separate genus is, I think, rather doubtful.

Microcosmus.

- Branchial sac having six folds on each side.
  - *M. helleri.*
- Branchial sac having seven folds on each side.
  - Surface of test very rough and irregular.
    - *M. polymorphus.*
  - Surface of test not rough.
    - *M. propinquus.*

Microcosmus helleri, n.sp.

External appearance.—Shape longish, elliptical, with a projection at the anterior end; posterior end broad and rounded. Attached by a small area at the posterior end of the ventral edge. Branchial aperture at the anterior end of the dorsal edge, terminal, on a large projection, directed anteriorly. Atrial aperture on the dorsal edge, two-thirds of the way down, on a hemispherical projection, not so prominent as the branchial aperture, directed dorsally and posteriorly. Surface wrinkled and rough, but not covered with excrescences; branchial and atrial projections much corrugated and thickened; a few zoophytes, polyzoa, &c., adhering, especially on

* Heller, Untersuchungen über die Tunicaten des Adriatischen und Mittelmeeres, iii. Abth., Wien, 1877, p. 3.

the left side and posterior end. Colour, dull gamboge yellow, with a little reddish-brown at the posterior end and the left side. Length, 8 cm.; breadth, 4 cm.

Test leathery, rather thin except at the area of attachment and on the siphons. Inner surface white, with a few yellowish-brown patches.

Mantle strongly muscular on the right side and the dorsal part of left, membranous on the ventral part; musculature strong and regular.

The muscular band at the base of the branchial siphon, and just above the tentacle ring, bears four large bluntly conical processes projecting into the lumen of the tube.

Branchial sac with six folds on each side. The alternate transverse vessels larger than the intermediate ones. Internal longitudinal bars numerous, eight or nine on the folds and about twelve on the interspace, which has six wide and six narrow rows of meshes. The largest meshes have each six to eight stigmata.

Dorsal lamina plain.

Tentacles compound, twenty in number, large and small alternately.

Olfactory tubercle broadly cordate, both horns rolled inwards.

One specimen from Station 188 (between Australia and New Guinea), 28 fathoms.

This species externally is not unlike *Microcosmus polymorphus*, Heller, but differs from it notably in having only six folds in its branchial sac, in the condition of the test, and in having projections n the branchial siphon above the circlet of tentacles.

Microcosmus polymorphus, Heller.*

One large specimen from Station 162 (Bass' Strait), 38 to 40 fathoms.

Microcosmus propinquus, n. sp.

External appearance.—Shape oblong-ovate, or almost triangular, flattened laterally; anterior end narrow, dorsal and ventral edges

* Heller, *loc. cit.* p. 6.

sloping backwards to the broad and rounded posterior end. Attached by the posterior two-fifths of the ventral edge. Branchial aperture terminal, on a large projection turned ventrally and to the left side; atrial aperture also prominent, on the dorsal edge, three-fourths of the way down, and directed dorsally. Surface wrinkled and minutely grooved, but not covered with excrescences; somewhat corrugated round the apertures, a few foreign bodies adhering. Colour pale yellow, with a reddish-brown tinge here and there. Length, 7·5 cm.; breadth, 5 cm.

Test leathery, tough, rather thin. Inner surface white and glistening.

Mantle strongly muscular on the right side; membranous over the viscera. A narrow membrane projects into the branchial siphon above the tentacular circlet; it is slightly crenated, but does not bear large conical processes as in *M. helleri.*

Branchial sac with seven folds on each side. Internal longitudinal bars numerous; about six on the folds, and the same number on the interspaces. Meshes transversely elongated, containing each about twelve stigmata; generally a fine transverse vessel divides the mesh horizontally.

Dorsal lamina not broad, but rather thick; edge plain.

Endostyle very broad.

Tentacles about twenty in number—six large, six small, and some intermediate very minute ones not present in all the interspaces.

Olfactory tubercle irregularly cordate; both ends turned in.

One specimen from Station 162 (Bass' Strait), 38 to 40 fathoms.

This species is nearly allied to *M. helleri*, from which it differs chiefly in having fourteen folds in its branchial sac instead of twelve, and in the condition of the diaphragm in the branchial siphon.

Cynthia, Savigny.

This genus is used here in the most restricted sense, as proposed by Heller:*—

* Untersuch. ü. d. Tun. Adriat. u. Mittelm., iii. Abth. p. 9.

Branchial sac with six folds on each side.	Tentacles simply pinnate			*C. fissa.*
	Tentacles much branched.	Opening of olfactory tubercle lateral; horns much coiled.		*C. cerebriformis.*
		Opening of olfactory tubercle anterior; horns slightly coiled.	Languets borne on a broad lamina.	*C. formosa.*
			Languets not borne on a lamina.	*C. arenosa.*
Branchial sac with seven folds on each side				*C. irregularis.*
,, ,, eight ,, ,,				*C. pallida.*
,, ,, nine ,, ,,				*C. hispida.*
,, ,, eleven ,, ,,				*C. complanata.*

Cynthia cerebriformis, n. sp.

External appearance.—Shape irregularly pyriform; anterior end wide and bent over greatly to the right side, which is concave, while the left is prominent and convex; posterior end drawn out into a short stalk, tapering to the point of attachment. Apertures not distant, both terminal, at the anterior edge of the right side, slightly projecting, directed to the right and a little anteriorly. Surface sulcated all over so as closely to resemble the convoluted surface of a brain; four large convolutions lead up to each aperture; posterior end and stalk wrinkled, but not sulcated like the rest. Colour dirty yellowish-white, becoming brown on the stalk. Length, 6·5 cm.; breadth, 4·7 cm.

Test thick, very stiff and solid; white on section and on the inner surface.

Mantle very thick; muscular at the anterior end. Branchial siphon short and wide; atrial narrower, but nearly twice as long.

Branchial sac with six folds on each side. Internal longitudinal bars numerous, about nine on a fold, and the same number in the interspace. Meshes occasionally divided by narrow horizontal membranes, and containing each six stigmata.

Dorsal lamina represented by a series of closely-placed stout tapering languets.

Tentacles branched, twenty in number—ten large and ten small placed alternately.

Olfactory tubercle rather large, elliptical in outline, placed with

its transverse axis directed anteriorly and posteriorly, the opening being at the right side; both horns turned in and forming moderately large spirals.

Viscera—Œsophageal opening very far forwards in the branchial, sac.

One specimen from Port Jackson, 6 to 15 fathoms.

Cynthia fissa, n. sp.

External appearance.—Shape ovate, with a deep cleft at the anterior end of the dorsal edge extending nearly half-way down, slightly flattened laterally; attached by the posterior end and nearly the posterior half of the left side. Apertures prominent, at the extremities of the two projections formed by the cleft; branchial projection terminal, atrial on the dorsal edge, fully half-way down, not so long as the branchial. Surface very irregular, much wrinkled and rough; on the right side the chief wrinkles run transversely. Colour yellowish-brown. Length, 2 cm.; breadth, 1·6 cm.

Test strong and stiff; white on the inner surface.

Mantle thick.

Branchial sac with six folds on each side. Six internal longitudinal bars on a fold, and three in the interspace. Meshes containing each six to eight stigmata, and sometimes divided by a narrow horizontal membrane.

Dorsal lamina with tentacular languets.

Tentacles simply pinnate, about twelve in number.

Olfactory tubercle large, irregularly oblong, aperture anterior; both horns turned to the left.

Several specimens adhering to the test of *Microcosmus polymorphus*, from Station 162 (Bass' Strait), 38 to 40 fathoms.

Cynthia formosa, n. sp.

External appearance.—Composed of a spherical body and a narrow stalk. Posterior end of the body rounded, anterior rather flatter; dorsal edge slightly more convex than ventral. Stalk about as long as the body, twisted, narrow, expanding slightly at the lower end where it is attached. Apertures both at the anterior end,

not distant, prominent. Surface smooth on the posterior half of the body; covered with fine silky spines on the anterior half, these increase in size towards the anterior end and culminate in sheaves of long bristles, which surround and hide the apertures. Colour grey. Length of body, 1·5 cm.; breadth, 1·3 cm.; length of stalk, 1·6 cm.

Test thin but tough; semi-transparent on the posterior half of the body.

Mantle thin but muscular; muscle bands forming a close network.

Branchial sac with six folds on each side. Internal longitudinal bars ribbon-like, about eight on a fold and four in the interspaces. Meshes transversely elongated, divided horizontally by three narrow membranes, and containing each nine or ten stigmata.

Dorsal lamina consisting of a series of small closely-placed languets borne on the edge of a broad lamina.

Tentacles large and much branched, about twelve in number.

Olfactory tubercle simple, transversely elliptical, opening anterior, horns turned inwards.

One specimen from Torres Straits, 3 to 11 fathoms.

Cynthia arenosa, n. sp.

External appearance.—Shape irregularly ovate or sub-triangular, elongated transversely, not compressed laterally; posterior end broad and rather flat, anterior narrow; dorsal and ventral edges convex; unattached. Apertures both at the anterior end, inconspicuous, placed close together, cross-slit. Surface entirely covered, with the exception of the siphons, by a close layer of sand grains. Colour grey. Length, 1·5 cm.; breadth, 1 cm.

Test thin, but very stiff on account of the imbedded sand.

Mantle thin, but strong; muscle bands well developed.

Branchial sac with six folds on each side. About five internal longitudinal bars on each fold, and the same number in the interspace. Meshes square, containing each about four stigmata, divided horizontally.

Dorsal lamina formed of a series of small tentacular languets.

Tentacles compound, few, long and short alternately.

Olfactory tubercle simple, rudely cordate in outline, opening anterior, both horns turned inwards.

Several specimens from Station 186 (Torres Straits), 1 to 8 fathoms.

Cynthia irregularis, n. sp.

External appearance.—Shape very irregular. Attached to a fragment of a shell by the right side near the dorsal edge and half-way up from the posterior end. Posterior end small, nearly flat; anterior end broad, deeply cleft between the large divergent siphons, on the extremities of which the apertures are placed. Branchial aperture at the ventral edge of the anterior end, prominent, turned ventrally and a little to the left; atrial aperture at the dorsal edge of the anterior end, not quite so prominent as the branchial, turned dorsally and a little to the left. Surface very uneven, deeply wrinkled, and rather rough. Colour yellow and dark brown. Length, 4·5 cm.; breadth, 3 cm.

Test thin, except at the posterior end where it is thickened, tough, and opaque; white on section and on the inner surface.

Mantle rather strong and muscular.

Branchial sac with the folds very slight and distant, seven on each side. Internal longitudinal bars numerous, about nine on a fold and eight in the interspace, which has four wide and four narrow rows of meshes. Meshes containing each four stigmata, and often divided by a narrow horizontal membrane.

Dorsal lamina formed of a series of narrow tentacular languets.

Tentacles compound, very small, twelve larger ones with either one or two very minute ones between each pair of these.

Olfactory tubercle very large but irregular; broken up into a number of curved pieces.

One specimen from Port Jackson, 2 to 10 fathoms.

Cynthia pallida, Heller.*

One specimen of this species from Simon's Bay, 10 to 20 fathoms; two from Kandavu, Fiji; and several small specimens from Papeete Harbour, Tahiti, 10 fathoms.

* Beiträge zur nähern Kenntniss der Tunicaten, p. 14, Taf. iii. figs. 17, 18 (Sitzb. d. k. Akad. d. Wiss., lxxvii. Bd., i. Abth., 1878).

The curious spicules mentioned by Heller as occurring in the mantle and branchial sac of this species are present in all the specimens. Smaller ones are also to be observed in the test. Similar spicules occur in a new species of *Cynthia* still to be described.

The specimens from Tahiti may turn out to be a new but closely allied species.

Cynthia hispida, n. sp.

External appearance.—Shape ovate or irregularly circular, flattened laterally, nearly as broad as long; dorsal and ventral edges strongly convex; anterior end broadish, straight. Attached by the rather narrow posterior end. Apertures both at the anterior end, moderately far apart, on short dome-like projections, the ends of which are conspicuously four cleft and covered with strong echinated hairs, which fringe the apertures; branchial directed anteriorly; atrial directed dorsally. Surface more or less wrinkled, and closely covered with a short down of prickly hairs, which occasionally at the posterior end, and most markedly round the apertures, increase in size and form large branched bristles. Colour dull brown, rather lighter round the apertures. Length, 6·6 cm.; breadth, 5·6 cm.

Test not thick, leathery, tough; smooth and glistening on the inner surface.

Mantle thick, musculature very strong and close, especially on the siphons.

Branchial sac with nine folds on each side, the ventral folds, or those next the endostyle on each side, being very slight, and only reaching half-way to the dorsal lamina. The alternate transverse vessels wider than the intermediate ones. Internal longitudinal bars numerous, about twelve on a fold, and the same number in the interspace. Meshes containing each about four stigmata.

Dorsal lamina formed by very small languets.

Tentacles compound, about fourteen in number, and all about the same length.

Olfactory tubercle small, but very prominent, situated on a hemispherical projection, elongated transversely; both horns coiled inwards.

Two specimens from Station 162 (Bass' Straits), 38 to 40 fathoms. The larger specimen has the surface considerably more wrinkled and the apertures more prominent than in the other. Both are attached to the interior of bivalve shells.

Cynthia complanata, n. sp.

External appearance.—Shape elongated, oblong, pointed at the anterior end, flattened laterally; dorsal edge straight or slightly concave, ventral convex; posterior end wider than anterior, but narrow. Attached by the ventral edge of the posterior end. Branchial aperture terminal, quadrangular, tubular, wide; atrial on the dorsal edge one-third of the way down, slightly projecting, also quadrangular and wide. Surface irregular but smooth, slightly creased. Colour dirty white. Length, 5·6 cm.; breadth, 2·7 cm.

Test soft, cartilaginous; varies greatly in thickness; is thin on the anterior half, then becomes thicker, and the posterior third is a solid mass of test substance.

Mantle thin; musculature rather feeble; siphons very wide. Spicules in the mantle like those in *Cynthia pallida*, Heller, but longer and thinner.

Branchial sac with eleven folds on each side. Eight internal longitudinal bars on a fold and four in the interspace. Meshes slightly elongated transversely, containing each about five stigmata, and generally divided horizontally.

Dorsal lamina formed of short blunt membranous languets.

Tentacles branched, nine large and nine small placed alternately, and about eighteen very minute intermediate ones.

Olfactory tubercle.—Outline nearly circular, both horns turned inwards, much coiled.

One specimen from Port Jackson, 6 fathoms.

Styela, Macleay.

This term was proposed by Savigny to denote a tribe of the genus *Cynthia*, and was first, I believe, used as a generic name by Macleay * in 1823.

* Trans. Linn. Soc., vol. xiv.

Styela.

- Dorsal lamina in the form of languets.
  - *S. bythia.*
- Dorsal lamina ribbed transversely and slightly pectinated.
  - *S. flava.*
- Dorsal lamina plain, margin even.
  - Tentacles few, about 12.
    - Long and short alternately,
      - *S. squamosa.*
    - All one length.
      - Shape oblong; length = twice the breadth.
        - *S. oblonga.*
      - Shape hemispherical; length = breadth.
        - *S. glans.*
  - Tentacles at least 30.
    - Tentacles 30, all one length.
      - Mantle thick, free from test.
        - *S. gyrosa.*
      - Mantle thin, united to test.
        - Body stalked; horns of olfactory tubercle turned in.
          - *S. clava.*
        - Body sessile; horns of olfactory tubercle not turned in.
          - *S. convexa.*
    - Tentacles more than 30, large and small.
      - Only one internal longitudinal bar between each pair of folds.
        - *S. exigua.*
      - Several internal longitudinal bars between each pair of folds.
        - 20 large tentacles, and smaller intermediate ones.
          - *S. grandis*
        - 30 large tentacles, and smaller intermediate ones
          - *S. lactea.*

Styela bythia, n. sp.

External appearance.—Shape between cubical and hemispherical; anterior end broad and obtuse, dorsal and ventral edges sloping backwards and slightly outwards. Attached by a wide posterior end slightly expanded at the margin. Apertures sessile, inconspicuous, four cleft; branchial at the ventral and atrial at the dorsal end of the anterior extremity. Surface of the test flat but rough, especially at the anterior end. Colour dark-brown, paler at the posterior end. Length, 2 cm.; breadth, 1 cm.

Test thick, very stiff, but rather brittle; white on section and on the inner surface.

Mantle reddish-brown, moderately thick, closely united to the test.

Branchial sac with four folds on each side. There is a considerable space on each side between the endostyle and the ventral fold. Internal longitudinal bars extremely numerous and much crumpled. Meshes small, elongated vertically, containing each one or two stigmata, and divided horizontally.

Dorsal lamina in the form of languets.

One specimen from Station 160 (South of Australia); 2600 fathoms.

Styela flava, n. sp.

External appearance.—Shape rudely spherical, slightly elongated laterally; anterior end convex. Attached by the posterior end and half of each side to a piece of coral; dorsal and ventral edges free and rounded. Apertures sessile, 4-lobed, moderately far apart, at the opposite ends of the anterior extremity. Surface of the test flat, but minutely scaly; scales largest and most distinctly marked round the apertures. Colour light yellow, with a brownish tinge at the apertures; white on the area of attachment. Length (antero-posterior), 1·6 cm.; breadth (from side to side), 2·4 cm.; thickness (dorso-ventral), 2 cm.

Test thin, but very tough, opaque; white and glistening on the inner surface.

Mantle rather thin. Muscular bands numerous, but very fine.

Branchial sac with four folds on each side; folds very slight, being merely the approximation of a number of internal longitudinal bars. There are about ten at these places, and ten in the intermediate opener parts. Meshes square or elongated vertically, containing each four stigmata, and divided by a narrow horizontal membrane.

Endostyle conspicuous, rather wide, reddish-brown.

Dorsal lamina ribbed transversely, and slightly toothed at the edge.

Tentacles simple; three sizes—fifteen large, fifteen small, and about thirty very minute ones.

Olfactory tubercle, placed at the bottom (posterior extremity) of a rather deep peritubercular area; small and irregular in shape.

Intestine rather narrow; loop open.

One specimen from Station 320 (off the coast of Buenos Ayres), 600 fathoms.

Styela oblonga, n. sp.

External appearance.—Shape oblong, erect, broadest in the middle, tapering slightly towards the anterior end and more towards the posterior; anterior end straight, dorsal and ventral edges slightly convex; posterior end by which it is attached narrow. Apertures four-lobed, sessile, placed at the extremities of the anterior end. Surface finely wrinkled and rough on rather more than the anterior half, smoother and slightly encrusted with sand on the posterior part. Colour yellowish-brown, dull on the anterior half, brighter posteriorly. Length, 3·5 cm.; breadth, 2 cm.

Test not thick, but tough on the upper part; thinner below, except at the posterior end, where it is considerably thickened.

Mantle thin, musculature very delicate.

Branchial sac with four folds on each side, formed, as in the last species, merely by a crowding together of the internal longitudinal bars, six to nine being placed close together, and separated by wide spaces containing only three bars. Meshes elongated vertically, containing each only three stigmata, divided by a narrow horizontal membrane.

Dorsal lamina narrow, much crumpled, neither ribbed nor toothed.

Tentacles simple, rather large, twelve.

Olfactory tubercle rather prominent, cup-shaped; opening anterior, wide.

One specimen from Station 320 (off the coast of Buenos Ayres), 600 fathoms.

This species was probably buried in sand for nearly half its length.

Styela glans, n. sp.

External appearance.—Shape regular, between conical and hemispherical, the highest point at the ventral edge of the anterior

end; posterior end large and flat, attached to a piece of coral; dorsal edge more convex than ventral. Branchial aperture anterior, at the highest part near the ventral edge; atrial on the dorsal edge two-thirds of the way down; both are sessile and inconspicuous. Surface roughish, but regular. Colour dark reddish-brown. Length, 1·5 cm.; breadth, 1·2 cm.

Test not thick but tough, white on the inner surface.

Mantle very thin and membranous.

Branchial sac with four slight folds on each side, about five internal longitudinal bars being crowded together, and the same number placed further apart alternately. Meshes elongated vertically, containing each three stigmata, divided by a narrow horizontal membrane.

Dorsal lamina narrow.

Tentacles simple, few, of a moderate size.

Olfactory tubercle simple, nearly circular in outline.

One specimen from Station 320 (off the coast of Buenos Ayres), 600 fathoms.

Styela squamosa, n. sp.

External appearance.—Shape roughly hemispherical, the anterior end very large and rising somewhat to its ventral extremity; ventral edge nearly straight, dorsal gently convex. Attached by the wide posterior end. Apertures sessile, distant, and inconspicuous; branchial at the ventral end and atrial at the dorsal end of the anterior extremity. Surface smooth but scaly. Colour creamy white, slightly yellow in parts. Length, 2 cm.; breadth, 1·5 cm.

Test thick and solid, but soft.

Mantle very thin, adhering slightly to the test.

Branchial sac with two distinct folds on each side near the dorsal edge, and one or two more indistinct ones ventrally. Internal longitudinal bars numerous. Meshes slightly elongated vertically, containing each four or five stigmata, and divided horizontally.

Dorsal lamina plain; no ribs or teeth.

Tentacles larger and smaller alternately. The larger ones are short and stout.

Olfactory tubercle a simple elliptical tubercle, with no visible markings.

One specimen from Station 160 (South of Australia), 2600 fathoms.

Styela gyrosa, Heller.*

A considerable number of specimens, many of them united into masses and supported by a common stalk, from Port Jackson, 6 fathoms.

Styela grandis, n. sp.

External appearance.—Shape irregularly pyriform, the anterior end being large and somewhat globular, while the posterior narrows into a short thick stalk, by which the animal is attached. Ventral edge straight or slightly concave, dorsal long and strongly convex. Branchial aperture a little to the ventral edge of the anterior end, directed ventrally; atrial on the dorsal edge about one-third of the way down, directed dorsally and slightly anteriorly; both apertures sessile, and not distinctly lobed, but conspicuous. Surface irregular, but not rough, towards the base much corrugated transversely, the rest of the surface more or less seamed and wrinkled. Colour dirty-white, becoming slightly darker towards the base. Length, 9·5 cm.; breadth, 6 cm.

Test thin and soft, but fairly strong.

Mantle very delicate; closely united to the inner surface of the test. Musculature consisting chiefly of a number of fine bundles of fibres running longitudinally.

Branchial sac with four folds on each side, the most dorsal one on each side placed very close to the dorsal lamina. There are three internal longitudinal bars on each side of a fold, and about six in the interspace. The alternate transverse vessels are wider than the intermediate ones. The meshes are immensely elongated transversely, and contain each about twenty stigmata.

Dorsal lamina rather wide and perfectly plain, having no ribs or teeth.

* C. Heller, Untersuchungen über die Tunicaten des Adriatischen und Mittelmeeres, iii. Abth. p. 15, 1877.

Tentacles simple, there are twenty long ones with occasional small intermediate ones.

Olfactory tubercle heart shaped, both horns turned inwards.

Two specimens from Station 150 (south of Kerguelen Island), 150 fathoms.

Styela lactea, n. sp.

External appearance.—Shape nearly rectangular, from oblong to spherical, erect, not compressed; anterior end straight and wide; posterior end straight and nearly as wide; dorsal and ventral edges slightly convex. Attached by the whole of the posterior end. Apertures both anterior, nearly sessile, four cleft; branchial at the ventral edge of the anterior end, directed ventrally; atrial at the dorsal edge of the anterior end, directed anteriorly and dorsally. Surface smooth, but seamed with tranverse creases and slight folds, longitudinal ones here and there. Colour creamy white. Length, 4·5 cm.; breadth, 3·5 cm.

Test thick, but soft and flexible, quite opaque.

Mantle closely attached to the test. Musculature fine, longitudinal and transverse bands intersecting at right angles.

Branchial sac with four folds on each side. Internal longitudinal bars rather few; about six on a fold, few and distant in the interspace. Meshes greatly elongated transversely, some of those near the endostyle containing thirty to forty stigmata, they are occasionally divided by a narrow horizontal membrane.

Dorsal lamina plain, no ribs, margin even.

Tentacles filiform, about thirty very long thin ones, with intermediate shorter ones.

Olfactory tubercle large, transversely elliptical; both horns rolled inwards and forming large spiral coils.

Three specimens from Kerguelen Island, 10 to 100 fathoms.

Styela exigua, n. sp.

External appearance.—Shape quadrangular, a little longer than broad, somewhat compressed laterally; anterior end broad and nearly flat; posterior rather narrower and more rounded. Attached

slightly by the posterior end of the left side. Apertures sessile, inconspicuous; branchial terminal and median; atrial on the dorsal edge, one-fourth of the way down. Surface even, but partially covered by a thin coating of sand. Colour dirty grey. Length, 1 cm.; breadth, ·8 cm.

Test cartilaginous, thick but soft.

Mantle very thin, closely united to the test.

Branchial sac wide, with four folds on each side. The alternate transverse vessels wider than the intermediate ones. Internal longitudinal bars stout, six on each fold, and only one in the interspace. Meshes transversely elongated, containing each about six stigmata.

Dorsal lamina narrow, margin plain.

Tentacles simple, numerous, long and short alternately.

One specimen from Port Jackson, 2 to 10 fathoms.

Styela convexa, n. sp.

External appearance.—Shape rudely hemispherical or bluntly conical, not flattened; anterior end and sides convex, posterior end large, attached to a stone and slightly expanded at the edge. Branchial aperture terminal, rather to the ventral side of the middle of the anterior end, but forming its most prominent point; atrial aperture moderately distant, at the dorsal edge of the anterior end; both are sessile and inconspicuous. Surface moderately smooth, finely creased in all directions, especially round the apertures. Colour dull yellowish-brown, lighter on the margins of the posterior end. Length, 2 cm.; breadth (dorso-ventral), 2·6 cm.

Test thin but very tough, white on section.

Mantle closely united to the test, musculature fine but close.

Branchial sac with four folds on each side. About eight internal longitudinal bars on a fold, and the same number in the interspace. Meshes elongated vertically, containing each about three stigmata, and divided by a narrow horizontal membrane.

Dorsal lamina slightly crimped but plain, edge even.

Tentacles simple, stout, rather curled, about thirty in number, and all of much the same length.

Olfactory tubercle simply oval, aperture at the narrower anterior end; horns not coiled, nearly touching.

One specimen from Station 150 (South of Kerguelen Island), 150 fathoms.

Styela clava, n. sp.

External appearance.—Club-shaped, the pyriform body being supported on a stalk of variable length, erect, not compressed; anterior end narrow but generally straight for a short distance, from this the body widens rapidly for the first two-fifths of its length and then narrows more gradually in the remaining three-fifths, the posterior end being prolonged into the stalk, which is generally about equal to the body in length. Apertures at the anterior end, four cleft, more or less projecting, but minute and inconspicuous; branchial at the ventral edge of the anterior end, directed ventrally; atrial at the dorsal edge of the anterior end, more prominent than the branchial, and therefore more anterior, directed anteriorly. Surface very irregular; posterior half of the body and stalk creased longitudinally, anterior half of the body nearly covered by irregularly-shaped but smooth and blunt knobs mostly directed anteriorly. Colour dirty white, with occasionally a slight yellowish tinge. Length (total), about 7 cm.; breadth (at broadest part of head), about 2 cm.

Test tough but thin, and almost papery except on the knobs and processes.

Mantle very delicate and closely united to the test, musculature very feeble.

Branchial sac with four narrow folds on each side. Internal longitudinal bars rather numerous, about nine on a fold and twelve in the interspace. Meshes transversely elongated, containing each six stigmata, and occasionally divided by a narrow horizontal membrane.

Dorsal lamina smooth and plain, no ribs and no teeth.

Tentacles about thirty, rather closely placed, not large, all about the same length, but some rather stouter than others.

Olfactory tubercle transversely elongated, horns simply curled inwards.

Several specimens from Station 233*a* (Kobé, Japan), 8 to 50 fathoms.

Polycarpa, Heller.

This genus is very closely allied to *Styela*. It is convenient, however, to separate them on account of the large number of species in the *Styelinæ*. The chief difference between the two genera is in the condition of the genital glands.

Polycarpa.

- Mantle strong and free.
  - Test covered with sand.
    - Tents. 12 long and 12 short. — *P. tinctor.*
    - Tents. 20 long and 20 short. — *P. pilella.*
  - Test bare.
    - Stalked. — *P. pedata.*
    - Not stalked.
      - Tentacles all one length. — *P. irregularis.*
      - Tentacles of two lengths. — *P. sulcata.*
- Mantle thin and closely united to test.
  - Stalked.
    - Test green. — *P. viridis.*
    - Test not green. — *P. radicatus.*
  - Not stalked.
    - Test having hairs like *Molgula*. — *P. molguloides.*
    - Test not bearing hairs.
      - Test more or less sandy and stiff.
        - Olfactory tubercle oblong. — *P. rigida.*
        - Olfactory tubercle circular. — *P. longisiphonica.*
      - Test pliable, not sandy.
        - Shape hemispherical, test smooth. — *P. minuta.*
        - Shape oblong, test rough. — *P. quadrata.*

Polycarpa pedata, n. sp.

External appearance.—Irregularly club-shaped, consisting of a long stalk supporting a somewhat globular body produced anteriorly; posterior end broad and rounded, passing rapidly into the narrow stalk which is nearly as long as the body; ventral edge nearly straight, dorsal strongly convex in its posterior half, straight in the

anterior part. Attached by the extremity of the long narrow stalk. Branchial aperture terminal, very prominent, directed anteriorly; atrial on the dorsal edge about half-way down the body, projecting, directed anteriorly and dorsally; both are distinctly four cleft. Surface smooth but grooved and creased somewhat. Colour yellowish-white with a tinge of red on the stalk. Length (total), 10·5 cm.; breadth, 4 cm.

Test thin but tough.

Mantle moderately thick, adhering here and there to the test; musculature close but not strong.

Branchial sac with four folds on each side. Transverse vessels all one size. Internal longitudinal bars numerous. Meshes slightly elongated transversely, containing each five or six stigmata.

Dorsal lamina plain.

Tentacles long, of a brown colour, twenty-five, all one length.

Polycarps large; tentacular endocarps present.

One specimen from Station 212 (Philippine Islands), 10 to 20 fathoms.

Polycarpa irregularis, n. sp.

External appearance.—Shape irregularly oblong, somewhat pyriform, erect, rather compressed laterally. Anterior and posterior ends narrow, middle two-fourths wide, and having the dorsal and ventral edges parallel; ventral edge straight throughout, dorsal sloping in its anterior and posterior fourths, straight in its central two-fourths. Attached by the narrow but irregular posterior end. Branchial aperture terminal, prominent, surrounded by four large lobes and four small ones; atrial on the dorsal edge, rather more than one quarter of the way down, distinct. Surface very irregular, cut up by deep grooves and folds, and partially covered by foreign bodies. Colour dirty yellowish-white. Length, 6 cm.; breadth, 3·5 cm.

Test rather thick, tough; white and glistening on inner surface.

Mantle thin, musculature not strong.

Branchial sac with four folds on each side. Three narrow transverse vessels between each pair of wide ones. About eight internal longitudinal bars on the folds and twelve in the interspace. Meshes transversely elongated and containing each six stigmata.

Dorsal lamina narrow and smooth.

Tentacles linear, rather distant, twenty-four in number, coloured black, some rather smaller than others but not placed alternately.

Olfactory tubercle ovate, but with the narrow end placed posteriorly, much convoluted and marked with black. Intestinal loop wide.

Endocarps numerous, yellow, and rather small.

One specimen from Station 208 (Philippine Islands), 18 fathoms.

Polycarpa sulcata, n. sp.

External appearance.—Shape between ovate and pyramidal, not compressed; anterior end narrow but rounded, posterior end broad and rounded; ventral edge very convex, dorsal convex posteriorly and concave anteriorly. Attached by the posterior end of the ventral edge. Branchial aperture not terminal but twisted round to the dorsal edge, prominent, directed dorsally; atrial on the dorsal edge about half-way down, directed dorsally; both four-lobed, wide and conspicuous. Surface smooth but uneven, cut up by deep creases and folds into rounded pad-like projections. Colour dull creamy-white. Length, 5·5 cm.; breadth, 3·5 cm.

Test thick and tough but soft, not stiff. Inner surface white, with small dark dots over it.

Mantle thin, not adhering to the test, dark brown; musculature not strong.

Branchial sac with four narrow folds on each side. Three narrow transverse vessels between each pair of wide ones. Internal longitudinal bars few. Meshes transversely elongated, containing each about eight stigmata.

Dorsal lamina smooth, very narrow.

Tentacles, twelve, rather large but not very long, distant, with two or three very minute ones between each.

Olfactory tubercle large and irregular, spongy.

Three specimens from Banda, 17 fathoms.

Polycarpa pilella, n. sp.

External appearance.—Shape a little variable but generally spherical or ellipsoidal, occasionally rather pyriform, the posterior

end being narrower; not compressed, erect; anterior end wide, convex. Attached by the posterior end. Apertures both at the anterior end, moderately far apart, not conspicuous. Surface entirely covered by a layer of sand. Colour yellowish-brown. Length, 6 mm.; breadth, 4 mm.

Test thin but strong.

Mantle rather strong, muscular fibres delicate but very numerous, forming a close network.

Branchial sac with four folds on each side. Transverse vessels all equal in size. About eight internal longitudinal bars on the folds and the same number in the interspaces. Meshes vertically elongated, containing each three stigmata.

Dorsal lamina plain.

Tentacles filiform, about twenty large ones, with one or two smaller between each pair.

Olfactory tubercle irregularly horse-shoe shaped, both horns rolled inwards.

About a dozen specimens from Bahia, 7 to 20 fathoms.

Polycarpa tinctor, Quoy and Gaimard.*

About a dozen specimens of this species from Port Jackson, at depths varying from 2 to 15 fathoms.

Polycarpa viridis, n. sp.

External appearance.—Shape more or less pyriform, the anterior end being the broadest, and the posterior forming a short stalk, sometimes more elongated and twisted, by the lower end of which the animal is attached. Both apertures at the anterior end, generally a little to the right side; branchial terminal, or subterminal; atrial a short way down the dorsal edge, not distant from branchial; both four-lobed, sessile, inconspicuous. Surface not uneven but generally more or less covered by animals, sand, shell fragments, &c., adhering to it. Colour dull green, darkest in the neighbourhood of the apertures. Length, 3 cm.; breadth, 2·5 cm.

Test not thick but tough, rough externally from adhering sand, &c., of a beautiful dark-green colour throughout. Vessels very numerous, anastomosing frequently.

* Voyage de l'Astrolabe, Zoologie, tom. iii. p. 608, pl. xci. figs. 1, 2.

Mantle muscular, united to the test, of a dull green colour.

Branchial sac with four folds on each side. Three small transverse vessels between each pair of large ones. About eight internal longitudinal bars on the folds and four in the interspace. Meshes transversely elongated, containing each nine to twelve stigmata.

Dorsal lamina narrow, not ribbed, margin plain.

Tentacles simple, filiform, crowded, about seventy, long and short alternately.

Olfactory tubercle rudely circular in outline; left horn coiled outwards, the right inwards.

Polycarps numerous, on the inner surface of the mantle, 1 to 3 mm. in length.

Several specimens from Port Jackson, at depths of 6, 2 to 10, and 6 to 15 fathoms.

Polycarpa radicatus, n. sp.

External appearance.—Club-shaped, erect; consisting of a globular body, supported on a narrow stalk equalling it in length. Anterior end rather broader than posterior, which is continuous with the stalk; edges convex; stalk long and narrow, spreading out somewhat at the lower end, where it is attached. Apertures both at the anterior end, sessile, inconspicuous, lobes indistinct; branchial on the ventral edge of the anterior end, atrial about the centre, and slightly the more anterior of the two. Surface even, slightly sandy. Colour dull greyish-yellow. Length (total), 3·5 cm.; breadth, 1·7 cm.; length of body, 2 cm.

Test moderately thick, strong but not stiff.

Mantle closely united to test, thin.

Branchial sac with four folds on each side. Three narrow transverse vessels between each pair of wide ones. Internal longitudinal bars ribbon-like, close and numerous on the folds, few between. Meshes transversely elongated, and containing each six to twelve stigmata.

Dorsal lamina narrow.

Tentacles simple, numerous, about fifty, crowded, of different sizes, but not alternating.

Olfactory tubercle circular, one end turned out and one turned in.

Polycarps well-marked, yellow.

One specimen from Station 163 (off the south-east coast of Australia), 120 fathoms; and one specimen from Port Jackson, 6 fathoms.

Polycarpa molguloides, n. sp.

External appearance.—Shape transversely ovate or sausage-shaped; elongated dorso-ventrally and depressed; attached by the wide posterior end. Apertures distant, both on the anterior end (upper surface), inconspicuous. Surface entirely covered by a thick layer of sand, shells, &c. Colour dark-brown. Length (antero-posterior), 3 cm.; breadth (dorso-ventral), 7 cm.; thickness (lateral), 4 cm.

Test moderately thick, leathery, covered with branched hair-like processes, like these of *Molgula*, to which the sand-grains, &c., are attached.

Mantle closely adhering to the test, thick and rough, musculature feeble.

Branchial sac with four folds on each side. Tranverse vessels all of one size. Six internal longitudinal bars on the folds, and four on the interspace. Meshes transversely elongated, containing each twelve stigmata.

Dorsal lamina plain.

Tentacles numerous, crowded, all one length, of a dark-brown colour.

Polycarps only slightly projecting, imbedded in the thick mantle.

Two specimens from Station 162 (Bass' Straits), 38 to 40 fathoms.

Polycarpa rigida, n. sp.

External appearance.—Shape oblong, erect, anterior end pointed, dorsal and ventral edges nearly straight and parallel, posterior end nearly straight, moderately wide; attached by the posterior end. Branchial aperture terminal, projecting; atrial on the dorsal edge, fully one-third of the way down, projecting; both very indistinctly lobed. Surface even, but roughish, and partly covered by foreign bodies. Colour dull greyish-brown, dull yellow round the apertures. Length, 8 cm.; breadth, 3 cm.

Test not very thick, and not tough, but very stiff, like cardboard; white on section and on the inner surface.

Mantle thin and closely adhering to the test, musculature feeble.

Branchial sac with four folds on each side. Tranverse vessels all one size. About twelve internal longitudinal bars on the folds, and six on the interspace. Meshes transversely elongated, and containing twelve stigmata each.

Dorsal lamina narrow, plain; edge even.

Tentacles simple, close, crowded, stout, about forty, all one length.

Olfactory tubercle oblong, lying in a very large triangular peritubercular area, and directed forwards and to the left.

Polycarps deeply imbedded in the mantle. Intestinal loop very wide.

Two specimens from Station 162 (Bass' Straits), 38 to 40 fathoms.

Polycarpa longisiphonica, n. sp.

External appearance.—Shape oblong or somewhat flask-shaped, erect, posterior end large and rounded, anterior end narrow and pointed. Apparently not attached, or only slightly by the posterior third of the left side. Apertures conspicuous, at the ends of very long siphons; branchial terminal, directed anteriorly; atrial on the dorsal edge half-way down, directed dorsally and anteriorly, fully as long as the branchial siphon. Surface covered, except on the siphons, by a fine coating of sand and shell fragments. Colour dark-brown. Length, 7 cm.; breadth, 4 cm.

Test thin and brittle, but rather stiff.

Mantle thin, closely adhering to the test; musculature feeble.

Branchial sac with four folds on each side. Every fifth or sixth transverse vessel wider than the intermediate ones, which are all one size. Eight internal longitudinal bars on the folds, and about the same number on the interspace. Meshes square, occasionally divided by a narrow horizontal membrane, containing each four to six stigmata.

Dorsal lamina narrow and plain edged.

Tentacles not very long, rather distant, about eighteen, some shorter than others, but not placed alternately.

Olfactory tubercle circular in outline.

Polycarps numerous and large, yellow.

Three specimens from Port Jackson, 6 to 15 fathoms.

Polycarpa quadrata, n. sp.

External appearance.—Shape oblong or oval, erect, somewhat compressed laterally, both ends broad and rounded, dorsal and ventral edges nearly straight and parallel. Attached by the posterior end. Branchial aperture terminal, sessile, inconspicuous, minute; atrial more than one-third of the way down, on the dorsal edge, also minute and inconspicuous. Surface considerably creased in all directions, especially round the apertures. Colour dirty white. Length, 2 cm.; breadth, 1·6 cm.

Test not thick, tough and strong, but not stiff; white and glistening on the inner surface.

Mantle closely adhering to the test, very thin.

Branchial sac with four slight folds on each side. Internal longitudinal bars very numerous and close in the places where they form the folds. Meshes vertically elongated, usually divided by a narrow horizontal membrane, and containing each one to three stigmata.

Dorsal lamina plain.

Tentacles simple.

Olfactory tubercle ovate, very minute, placed at the posterior end of a deep peritubercular area.

Polycarps few, only three or four on each side. Endocarps numerous. Intestinal loop wide.

Three specimens adhering to the spicules of *Labaria hemispherica* from Ki Island, 129 fathoms.

Polycarpa minuta, n. sp.

External appearance.—Dome-shaped or nearly hemispherical; anterior end convex, posterior wide, flattened, attached, slightly expanded at the margin. Apertures both anterior, not distant, sessile but distinct. Surface perfectly smooth and even. Colour pale yellowish-brown. Length, ·6 cm.; breadth, ·9 cm.

Test thin, but tough and strong.

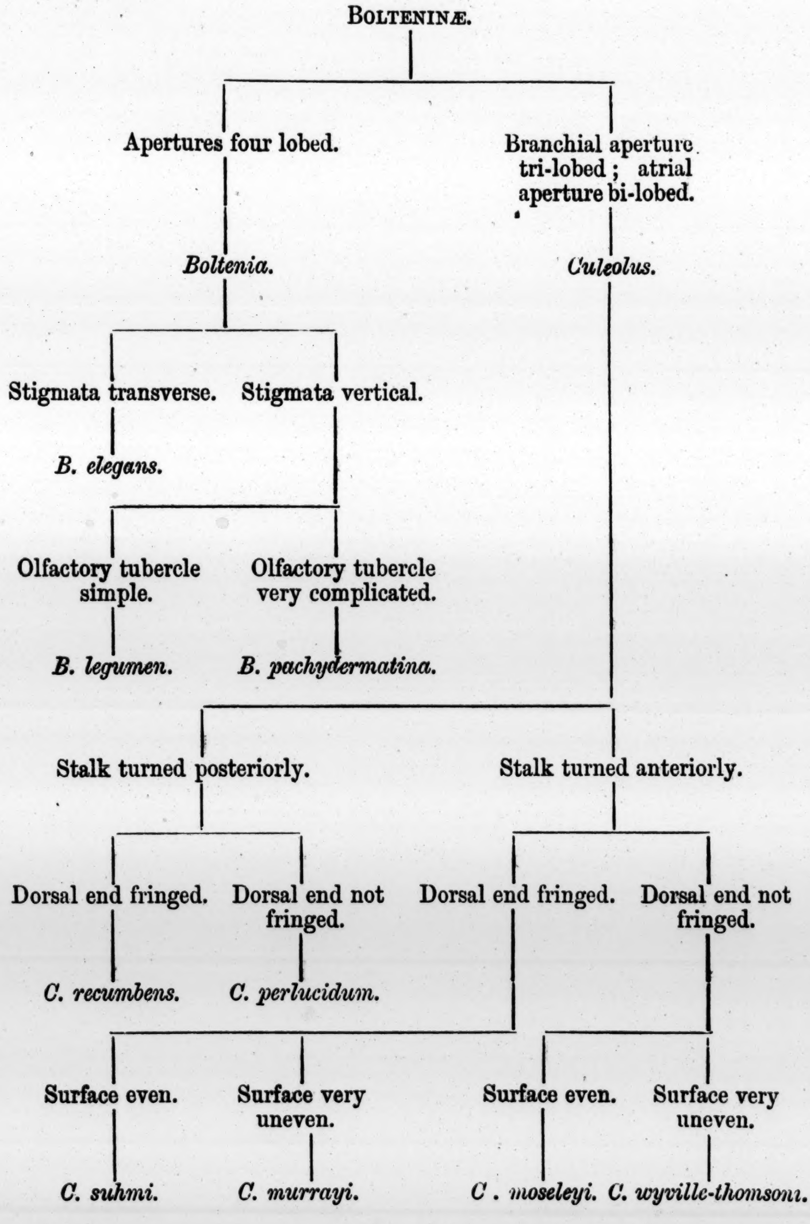
Mantle closely adhering to the test, very thin.

Branchial sac with four folds on each side. Transverse vessels all of the same size. Internal longitudinal bars very few, there being only two between each pair of folds. Meshes transversely elongated, containing each six to eight stigmata.

Dorsal lamina plain.

Tentacles many, filiform.

One specimen from Station 150 (south of Kerguelen Island), 150 fathoms.



Boltenia elegans, n. sp.

External appearance.—Shape of body quadrangular ovate, not flattened; anterior and posterior ends bluntly rounded, dorsal and ventral edges nearly straight. Peduncle long and thin, wiry, attached to the ventral edge of the anterior end, and turned slightly ventrally. Apertures conspicuous, branchial at the dorsal edge of the anterior end, directed anteriorly and dorsally; atrial on the dorsal edge, two-thirds of the way down, directed dorsally and posteriorly; behind the atrial aperture the dorsal edge sinks in somewhat towards the posterior end. Surface smooth and glistening, marked by a few creases. Colour of the body white, with a satiny lustre; stalk light yellowish-brown. Length of body, 5·5 cm.; breadth of body, 4 cm. Length of stalk, 36 cm.; thickness of stalk, 2 mm.

Test thin but tough.

Mantle strong, musculature regular.

Branchial sac with nine folds on each side, those next the endostyle being closer than the dorsal ones. Transverse vessels wide and distant. Stigmata transverse, running between narrow longitudinal bars which connect the transverse vessels. Internal longitudinal bars narrow but well marked, running at right angles to the transverse stigmata. Stigmata rather long and narrow, about fifteen in each mesh.

Dorsal lamina represented by a series of closely-placed, large, tapering languets.

Tentacles large, branched, sixteen in number, placed long and short alternately.

Olfactory tubercle large and distinct, elongated transversely but directed vertically, the opening being on the right side; both horns coiled inwards.

Two specimens from Station 48 (south of Halifax, N.S.), 51 fathoms.

This species is probably nearer to Savigny's *Boltenia ovifera* than to any other known species, but differs from it in many particulars.

Boltenia legumen, Lesson.*

Station 312 (Straits of Magellan), 10 to 15 fathoms, one specimen.

Station 315 (East of Falkland Islands), 5 to 10 fathoms, eight specimens.

Station 316 (East of Falkland Islands), 4 to 5 fathoms, one specimen.

Boltenia pachydermatina, n. sp.

External appearance.—Shape of body ovate to fusiform, compressed laterally; posterior (upper) end bluntly pointed, anterior end narrow, becoming gradually continuous with the stalk; dorsal edge more convex than ventral. Stalk long, thick, twisted, and creased, rather tapering downwards towards the point of attachment. Apertures conspicuous but not prominent, not distant, placed at the points of junction of the middle with respectively the anterior and posterior thirds of the body. Surface of body smooth but deeply grooved longitudinally, stalk closely wrinkled transversely. Colour of the body dull creamy-white, of the stalk yellowish-brown. Length of body, 10 cm.; breadth, 5 cm.; length of stalk about 20 cm.

Test very thick and stiff, between cartilaginous and coriaceous, tough; white and glistening on the inner surface.

Mantle thin but muscular, slightly adhering to the test.

Branchial sac with about six folds on each side. Internal longitudinal bars numerous, about eight on the folds and six in the interspace. Meshes transversely elongated, containing each about nine stigmata, always divided horizontally by a narrow bar.

Tentacles compound, densely branched, sixteen in number, placed large and small alternately. One tentacle much larger than any of the others.

Olfactory tubercle large, circular, the surface marked with a close and elaborate pattern.

One large and one small specimen from Canterbury, New Zealand.

* Centurie Zoologique, p. 149, pl. liii. fig. 1, 1830.

Culeolus, n. gen.

Body more or less ovate, stalked.

Branchial aperture three-lobed.

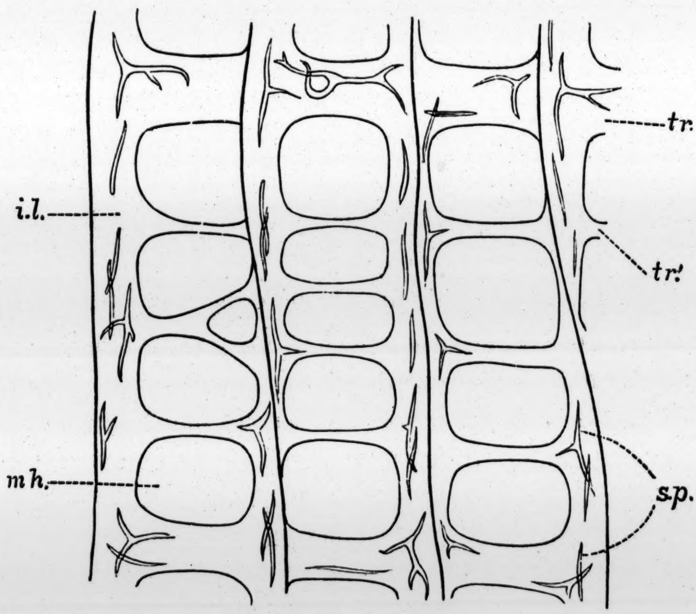
Atrial aperture bi-lobed.

Branchial sac longitudinally folded, consisting of longitudinal and transverse bars. No stigmata, the fine longitudinal vessels being absent.

Tentacles compound.

This genus is formed for the reception of a remarkable little group of six deep-sea species of stalked Simple Ascidians, which were at the first glance referred to *Boltenia*. They must still be considered as near allies of that genus but they differ from it in several important details of structure.

In addition to the characters in the above description, mention must be made of a system of branched calcareous spicules found



Branchial sac in *Culeolus*.
tr., Large transverse vesssel; *tr'.*, small transverse vessel; *il.*, internal longitudinal bar; *mh.*, mesh; *sp.*, spicula.

in the vessels of the branchial sac, &c., and more or less developed in all the species (see woodcut).

The most remarkable peculiarity of this genus is the structure of the branchial sac. It is merely a skeleton compared with that organ in other Simple Ascidians. The system of fine longitudinal or inter-stigmatic vessels is entirely wanting, so that the large meshes are not broken up into true stigmata. It seems probable from Macleay's description * that the branchial sac of *Cystingia griffithsii* has a similar simple structure.

Culeolus murrayi, n. sp.

External appearance.—Shape of the body irregularly pyriform, anterior end attenuated, ending in the stalk; posterior end blunt and broad, dorsal and ventral edges nearly straight and parallel in their posterior two-thirds, tapering suddenly in the anterior third. Stalk of moderate length, turned towards the branchial aperture. Branchial aperture placed rather on the dorsal side of the anterior end, being under the stalk, which is terminal. Atrial aperture in the middle of the posterior end, and directed posteriorly. Surface very irregular, thrown into deep creases; a belt of close-set minute projections surrounds the atrial opening, cutting off the posterior third by a very irregular line. The rest of the surface is finely granulated, the granulations being larger in the neighbourhood of the apertures. Length of body, 6 cm.; breadth, 4 cm.; length of stalk, 15 cm.

Test moderately thick, tough but soft and flexible; quite opaque.

Mantle adhering to the test, but easily separated, thin; muscle bands strong, but distant.

Branchial sac large and delicate, having six folds on each side, those at the dorsal edge closer and more distinct than those at the ventral, the pair next the endostyle being very slight. Transverse vessels alternately larger and smaller. Internal longitudinal bars wide, four between each pair of folds. Meshes vertically elongated, large. Spicules in the vessels large and branched.

Endostyle conspicuous, white, and very irregular in its course; richly supplied with large and much branched spicules, having a definite arrangement.

* Trans. Linn. Soc., vol. xiv. 1823.

Dorsal lamina represented by a series of large languets placed close together.

Tentacles much branched, of various sizes, some being very large.

Olfactory tubercle small but distinct, crescentic in shape, with the opening on the left side; both horns rolled inwards.

Viscera.—Wall of stomach remarkably folded. Genital masses about twelve in number, united in pairs and placed on the inner side of the mantle on both sides of the endostyle, the majority being on the right side.

Two specimens from Station 241 (Pacific Ocean, east of Japan); 2300 fathoms.

Culeolus wyville-thomsoni, n. sp.

External appearance.—Shape of the body irregularly pyriform or wedge-shaped, the anterior end being narrow, while the posterior is broad and blunt; dorsal and ventral edges sloping irregularly from the broad posterior end to the narrow anterior end, where the stalk is attached. Stalk thin, not long, wiry, running a slight way along the ventral edge from its point of attachment, turned towards the branchial aperture. Branchial aperture a little dorsal to the anterior end, being behind the stalk, directed anteriorly and a little dorsally; atrial aperture in the centre of the posterior end, directed posteriorly. Surface irregular, deeply seamed and raised between the seams into eminences, capped with slight papillæ. Colour pale slaty grey. Length of body, 5 cm.; breadth, 4 cm.; thickness (lateral), 3·5 cm.; length of stalk, 10·5 cm.

Test cartilaginous, thick but soft, not flexible.

Mantle thin; muscle bands strong, but rather distant.

Branchial sac with six folds on each side, diminishing in size from the dorsal to the ventral edge, those next the endostyle being very slight. Transverse vessels of three sizes placed in the following manner:—a large one, three small ones, a middle-sized one, three small ones, and then a large one; thus, any two large ones are separated by a middle-sized one and six small ones. Meshes small, transversely elongated. Spicules smaller and not so much branched as in *Culeolus murrayi*, but more numerous.

Dorsal lamina separated by a series of close-set large languets.

Tentacles about sixteen in number, branched, large and small alternately, but rather irregular in size; the tentacle at or just to the left of the olfactory tubercle is gigantic.

Olfactory tubercle distinct, cordate, opening on the right side, both ends turned in.

One specimen from Station 170 (north of the Kermadec Islands, South Pacific Ocean), 500 fathoms.

Culeolus recumbens, n. sp.

External appearance.—Shape of the body irregularly quadrate, with the angles rounded, both ends blunt; anterior rather narrower than posterior, and posterior rather more convex than anterior; dorsal and ventral edges nearly parallel, tapering slightly anteriorly, dorsal nearly straight, ventral a little convex. Stalk attached at the anterior end, on the ventral side of the branchial aperture from which it turns; it is long, thin, and like a piece of string. Branchial aperture terminal and medium; atrial on the dorsal edge two-thirds of the way down, directed dorsally. Surface even and pretty smooth, here and there slightly granulated, a band of close-set slight projections forming a line cutting off about a fourth at the hinder end, from the atrial apertures dorsally to the edge of the posterior end ventrally. Colour pale yellowish-white. Length of body, 2·5 cm.; breadth, 1·7 cm.; thickness, 1·5 cm.; length of stalk about 14 cm.

Test thin but tough, semi-opaque.

Mantle very thin, closely adhering to test, musculature feeble.

Branchial sac.—Folds very straight. Transverse vessels all the same size. Internal longitudinal bars wide. Meshes large, elongated vertically. Spicules very small but ramifying and numerous.

Dorsal lamina formed by large triangular languets.

Tentacles very long, about twenty-four in number, large and small alternately.

Olfactory tubercle small, ellipsoidal, with no aperture.

Viscera. Three genital glands on each side of cloaca.

Several specimens from Station 146 (between Cape of Good Hope and Kerguelen Island), 1375 fathoms.

Culeolus perlucidum, n. sp.

External appearance.—Shape of body ovate, the anterior end being narrow, while the posterior is round but not very broad; dorsal edge slightly, and ventral edge extremely convex. Stalk long and thin, attached to the anterior end, which tapers into it, turned away from the branchial aperture. Branchial aperture on the dorsal edge about one-fourth of the way down from the stalk; atrial at the dorsal edge of the posterior end, directed dorsally and posteriorly; both apertures prominent. Surface even and nearly smooth, being slightly granulated here and there. Colour light grey. Length of body, 2 cm.; breadth, 1·4 cm.; length of stalk about 11 cm.

Test very thin but tough, quite transparent.

Mantle thin, not adhering to the test, musculature fine but irregular.

Branchial sac very delicate. Transverse vessels wide and narrow alternately. Meshes nearly square. Spicules minute and very few.

Dorsal lamina.—Languets rather close and wide, tapering to a point.

Tentacles numerous; a few rather large, much branched, and a considerable number of small intermediate ones of different sizes.

Viscera.—One large genital gland on each side.

Several specimens from Station 147 (between Cape of Good Hope and Kerguelen Island), 1600 fathoms.

Culeolus suhmi, n. sp.

External appearance.—Shape of body between ovate and wedge-shaped; anterior end narrow, posterior end wide; ventral edge nearly straight, dorsal edge strongly convex. Stalk attached a little on the ventral side of the anterior end and turned towards the branchial aperture, of moderate length, thin. Branchial aperture prominent, terminal, and medium; atrial, on the dorsal edge, fully two-thirds of the way down, directed dorsally and slightly posteriorly. Surface even, granulated all over, and having a band of close-set projections cutting off a third of the body posteriorly and dorsally, being directed obliquely from about half-way down

the dorsal edge to the posterior end of the ventral edge, where it forms a projection. Colour dark-brown. Length of body, 1·5 cm.; breadth, ·9 cm.; length of stalk, 6 cm.

Test thin but stiff, quite opaque.

Mantle very delicate, musculature feeble.

Branchial sac.—Folds slight. Transverse vessels all one size. Internal longitudinal bars wide. Meshes nearly square, usually rather elongated transversely. Spicules large and branched, not very numerous.

Dorsal lamina formed of large blunt languets.

Tentacles branched, sixteen in number, long and short alternately.

One specimen from Station 44 (off the east coast of North America), 1700 fathoms.

Culeolus moseleyi, n. sp.

External appearance.—Shape of body regularly pyriform, anterior end attenuated and produced, being continued into the long thin stalk; posterior end wide and rounded; dorsal and ventral edges similar, convex, the anterior half of each tapering. Stalk turned towards the branchial aperture, which is on the dorsal edge, nearly one-fourth of the way down, and directed dorsally and anteriorly; atrial in the centre of the posterior end, directed posteriorly. Surface even but rough, being equally granulated all over. Colour pale yellow. Stalk marked with a fine reticulation of a brown colour. Length of body, 2 cm.; breadth, 1·2 cm.; length of stalk about 9 cm.

Test rather thick and stiff, quite opaque.

Mantle thin, muscle bands strong, but distant.

Branchial sac.—Folds slight. Transverse vessels all the same size. Internal longitudinal bars wide. Meshes square. Occasional fine transverse and longitudinal bars cross the meshes, but they are rarely seen, and do not extend for any distance. Spicules very large and branched, numerous.

Dorsal lamina. Languets.

Tentacles small, very delicate, with only occasional minute branches.

Olfactory tubercle with the opening turned towards the right side; anterior horn turned outwards, posterior coiled outwards.

One specimen from Station 271 (in the centre of the Pacific Ocean), 2425 fathoms.

These six species of *Culeolus* are all from upwards of 500 fathoms; five of them are from over 1000 fathoms, four from over 1500, and two from upwards of 2000 fathoms. They all belong to the abyssal zone.

In connection with the uniformity of the abyssal fauna, it is interesting to note that these six species, the only deep-water Bolteninæ, all belong to one genus, notwithstanding their wide distribution in space;—one species being from the North Atlantic, two from the Southern Ocean, one from the South Pacific, one from the North Pacific, and one from the centre of the Pacific Ocean on the equator.

Besides *Culeolus*, the only genus in the Cynthiadæ represented at depths of over 500 fathoms is *Styela*. Three species, *S. flava*, *S. oblonga*, and *S. glans*, were obtained from 600 fathoms, and two, *S. bythia*, and *S. squamosa*, from 2600 fathoms; these are perfectly normal members of the large and widely distributed shallow-water genus *Styela*. The great majority of the remaining species described in the present part are from depths of less than 50 fathoms.

2. On the Histology of the Pedicellariæ and the Muscles in *Echinus sphæra*, Forbes. By Patrick Geddes, F.R.S.E., Lecturer on Zoology in the School of Medicine, Edinburgh, and Frank E. Beddard, B.A., Assistant-Demonstrator of Zoology, Oxford.

(*Abstract.*)

This paper contains a detailed account of the structure of the soft parts of the four varieties of Pedicellariæ in this species describes particularly certain new pseudo-skeletal structures, and concludes with a reconciliation of the hitherto contradictory views as to the structure of Echinoderm muscles.

3. Additional Note on an Ultra-Neptunian Planet. By Professor George Forbes.

On the 16th of February 1880 I communicated to the Society a research upon Comets, which led me to believe in the existence of two new planets outside the orbit of Neptune. This memoir was not published in the "Transactions," and only a short abstract appeared in the Proceedings of the Society. A small number of copies were privately printed; but any one wishing for information on the subject will find it most readily in the "Observatory," 1880, June 1.

The decided tendency of the aphelia of comets to group themselves at distances from the sun equal to those of the planets could leave no doubt about the *existence* of these two new planets. The only doubtful point was as to the positions of the planets in their orbits. Meantime this research gives us greater confidence in the accuracy of the orbits of comets which have been calculated. This is most especially the case with the periods of revolution of comets when those periods are long, an element which has hitherto been very generally mistrusted. The most remarkable case is that of the comet 1861, which was calculated by Oppolzer to have a period of 415 years, and which I showed to have returned three times at such an interval.

It is well here to remark that, even in those cases where planetary perturbations may have occurred, it is seldom that the omission to take account of these could give rise to serious error, since a mistake of ten years in the date of reaching the aphelion would affect the longitude of the planet only to a trifling extent.

At present I have to speak only of the nearest of the two new planets. It was shown in the previous research to lie, in the year 1880, either close to the ecliptic in longitude 174°, or else on an orbit inclined to the ecliptic at 53°, with the longitude of the ascending node at 253°, the longitude of the planet on this orbit being 185°. The coincidences in the times of the comets arriving at their aphelia, and the times of a hypothetical planet reaching those positions, were so striking as to leave little doubt about one of these two being the true position.

This result was confirmed in a second research communicated to the Society, 1880.

Here I treated of the disturbances produced by the new planet on the longitude of Uranus, as shown by its residual tabular errors, favouring the hypothesis of the new planet moving nearly on the ecliptic. This research leaves not the slightest doubt about the longitude of the new planet, agreeing precisely with my previous work on comets.

I was able further, by a comparison of the periodic fluctuations in these residual errors with the periodic fluctuations in the longitude of Uranus, produced by the action of Neptune (for which I am indebted to Professor Newcomb's "Theory of Uranus," p. 100, &c.), to compare directly the map of Neptune with that of the new planet. By an easy harmonic analysis, the effect of Neptune is found to be about ten times that of the new planet. But the new planet is three times farther from the sun than Neptune, and the action is proportional inversely to the cube of the distance in equal times. Moreover, in the case of Neptune, the period during which this action lasts is 75 years, while in the case of the new planet it is only 45 years; and the effects are proportional to the squares of the times. Hence the mass of the new planet is to that of Neptune in the ratio of

$$\frac{1}{10} \times 3^3 \times \frac{75^2}{45^2} : 1 = 10 : 1 \text{ nearly.}$$

The mass of Neptune adopted by Newcomb was $\frac{1}{19640}$. This makes the mass of the new planet $= \frac{1}{1964}$, the mass of the sun being unity. This is the newest result at which I have arrived after a most careful examination. The new planet is then the largest but one in the solar system.

It occurred to me lately that, with these well-defined perturbations, it will be easy to decide between the two hypotheses discussed in my first memoir. For if the new planet be at present in a position so very far from the ecliptic as is indicated by the first hypothesis, then we should expect to find periodical fluctuations in the residual tabular errors of the latitude of Uranus. In fact, we might even hope by this means to determine its latitude approximately. [As a first approximation the latitude of the new planet may without serious error be considered constant during a period of

half a century.] The period of revolution of Uranus is 84 years, whilst its period synoclical with the new planet is 92 years. It is unfortunate that these periods are so nearly alike, because it makes it difficult for harmonic analysis to discriminate between those errors of latitude due to errors in the assumed inclination and longitude of ascending node, and those which are due to the action of the new planet. Nevertheless, any large effect as we should expect upon the first hypothesis ought clearly to be distinguished. The errors of latitude are taken from Newcomb, p. 176. They are very small in the last 50 years, but show a marked periodic fluctuation of about 92 years. There are two dates, however—1861 and 1864—when the errors are completely discordant. I think we may with reason reject these two on the ground that up to 1861 the observations used were almost entirely those of Greenwich and Paris. Those after 1868 are almost entirely Greenwich and Washington; while between these dates those of Greenwich, Paris, Washington, and Leyden are used. We have then residual periodic fluctuation, due to the action of the new planet from which we are able to determine its latitude. In this way I find its probable latitude to be about 2° south.

This may not, perhaps, be extremely accurate, but it completely establishes the truth of the *second* hypothesis.

Although from my study of Uranus I had no doubt about the accuracy of the conclusions in my first memoir, still it was with some gratification that I received the following letter from Mr D. P. Todd, of the Nautical Almanac Office in Washington:—

"Nautical Almanac Office,
"Navy Department, Washington, 15*th June* 1880.

"Dear Sir,—About a month ago I read with intense interest a copy of your memoirs "On Comets and Ultra-Neptune Planets,' which came to this office. You cannot fail of understanding my enthusiasm about the matter, in so far at least as it relates to the prediction of position, when I tell you that some three years ago I was engaged on a provisional treatment of residuals of longitude of Uranus and Neptune, having in view the detection of possible exterior perturbations. On my first reading of your paper I took the notion in some way that your assigned longitude was a long

way different from mine, and I thought nothing more about it for several days; but then, on referring to my papers, what was my astonishment and delight on finding that your position for the interior of the two planets differs *only four degrees* from the position which I had assigned from my own work, and marked upon a slip of paper on the morning of the 10th October 1877. Of course all my work was necessarily inconclusive, as there are not, even up to the present moment, any well-marked residuals in the case of either Uranus or Neptune; so I have never yet published the investigation. But, at the same time, I thought well enough of the work to attempt a practical search for a trans-Neptunian planet. It was conducted with the great refractor of the Naval Observatary during the latter part of 1877 and early in 1878. By reference to my observing book, I find that the investigation to which I have alluded led me to begin the search at longitude 146°. I have not my papers here at the office; but, if my memory is right, I arrived at a position in longitude somewhat less than 170°, on a date later by a few days than that I previously mentioned; and I further believe that I decided to begin the search at a point some fifteen to twenty degrees preceding that indicated as most probable by my research. I found the practical search much the most arduous task that I had ever set myself about, and the matter was the more aggravating because my regular day work could suffer no interruptions, and the great telescope was not at my service until after midnight. Furthermore, my residence was something like two miles distant from the Observatory, and I had no assistance whatever in the dome. The search was abruptly terminated, by circumstances beyond my control, at longitude 186°. But as I took only a narrow zone, at a given inclination so elliptic, I have never regarded the search definitive. I have not yet fully concluded what I shall do—if anything—with my investigation. I think, however, that if I have leisure during the next few months, I shall repeat the work quite independently of what I previously did, and publish at least the results, if there seems to be anything worth the while.—I am, dear Sir, yours, with much respect,

"(Signed) D. P. Todd.

"*To* Professor George Forbes, M.A.,

"Anderson's College, Glasgow, Scotland."

Mr Pliny Earle Chase, of Haverford College, forwarded a post-card, dated July 30, 1880, to the Royal Society of Edinburgh, which was handed to me, whose contents are as follows:—

" *Ultra-Neptunian Planets.* — Professor George Forbes' hypothetical planets are represented by my $\frac{\pi^n}{32}$ series (Proc. Amer. Phil. Soc., xiii. 140).

	Theoretical.		Observed.
$\frac{\pi^2}{32}$ =	·31	Mercury, perihelion, =	·31
$\frac{\pi^3}{32}$ =	·97	Earth, „ =	·98
$\frac{\pi^4}{32}$ =	3·04	Asteroids (= 2 + Mars), =	3·04
$\frac{\pi^5}{32}$ =	9·56	Saturn, =	9·54
$\frac{\pi^6}{32}$ =	30·04	Neptune, =	30·04
$\frac{\pi^7}{32}$ =	92·79	Forbes, I., =	100·00
$\frac{\pi^8}{32}$ =	296·52	Forbes, II., =	300·00."

In May 1880, the Earl of Craufurd and Balcarres, then Lord Lindsay, sent a circular from Dunecht, stating that I would forward a copy of my memoir to those who were likely to assist in the practical search. This led to a distribution of about 100 copies; in consequence of which a large number of excellent telescopes are now being employed in the search, and a considerable number of charts of that region have been forwarded to me. But hitherto the observations have been too few to expect results. Mr Newall kindly lent me his gigantic refractor; but during six weeks that I was on the watch I had not a single really good night.

With regard, then, to the future search for the planet, I would recommend (1) a search over a zone extending over about five degrees on each side of the position indicated by me, and going at least to two degrees south of the ecliptic. (2) I would recommend a special search in the position indicated by the stars observed by Rümker at Paramatta, mentioned in my last communication on this subject

to the Society, which I there surmised to be the new planet. I find that these stars were generally observed only once. The dates are not given in the catalogue, but they all lie on one great circle quite close to the ecliptic. They have never been observed by other astronomers. The mean position of these three stars is about 10h. 39m. R.A. I believe that the mean time of observation of these stars was about the year 1835. In 46 years the new planet would move over 15·5°, or 1h. 2m. This would make the present position of the new planet = 11h. 41m., agreeing within 1m. of the theoretical time.

4. On some Effects of Rotation in Liquid Jets. By Professor Tait.

The author had noticed that a jet of mercury from a funnel, falling horizontally and nearly tangentially on a slightly inclined glass plate, seemed to *roll upwards* along the plate. Attributing this to a rotation of the jet, he endeavoured, with success, to reproduce the phenomenon with water jets escaping from a rapidly rotating tube, and falling on a slightly inclined glass surface covered with a thin layer of paraffin.

Another curious fact was observed when the efflux was slow, and the tube rotated very rapidly. The water, on escaping from the rotating tube, instead of proceeding as a jet, crept round the fixed tube in which the rotating tube was enclosed, and escaped by dropping off at a distance of nearly half an inch from its open end.

5. Note on the Influence of Temperature-Change of Conductivity on the Conduction of Heat in Solids. By Professor Tait.

(The substance of this note is incorporated in the first of Professor Tait's papers of February 7, below.)

BUSINESS.

Sven Lovén, Director of the Museum and Professor of Natural History at Stockholm; Simon Newcomb, Professor, United States Navy, Washington; Émile Plantamour, Professor of Astronomy,

Observatory, Geneva; Johannes Iapetus Smith Steenstrup, Professor of Zoology at Copenhagen, were balloted for, and declared duly elected Foreign Honorary Fellows of the Society.

The Hon. Justice Grove, M.A., D.C.L., LL.D., and the Rev. George Salmon, D.D., D.C.L., LL.D., Regius Professor of Divinity, Trinity College, Dublin, were balloted for, and declared duly elected British Honorary Fellows of the Society.

Monday, 7th February 1881.

Professor DOUGLAS MACLAGAN, Vice-President, in the Chair.

The Chairman read Obituary Notices of Mr Thomas Key, Dr William Lassell, Mr Maurice Lothian, Mr Mungo Ponton, Mr Thomas Knox, The Hon. Lord Ormidale, Professor Sharpey —deceased Fellows of the Society.

OBITUARY NOTICES.

Thomas Key. By J. Sanderson, Deputy Inspector-General of Hospitals.

Mr Thomas Key, Licentiate of the College of Surgeons of Edinburgh, was a son of Dr Patrick Key, Physician in Forfar. He was born in that town in 1803, and received his early education there. He attended the literary classes at the St Andrews University before coming to the University of Edinburgh to study medicine. At the age of nineteen he received his diploma of Surgeon from the College of Surgeons of that city. In the following year he received the appointment of assistant-surgeon in the Madras Medical Service of the Honourable the East India Company.

Very shortly after his arrival in India, he was appointed to the Hydrabad Contingent Forces in the Deccan, in which he served sixteen years. During this time he held the office of medical storekeeper, and was also superintendent of the Medical School at Bolarum, which position he held till 1842. In that year he was compelled, from the state of his health, to resign his office and return to Europe.

During his service in the Nizam's Army in the Deccan, he several times received the thanks of the Resident for the efficient manner in which he had discharged his official duties, and also for having introduced a method of preparing certain medicines, which rendered it unnecessary to procure supplies of them from England.

While at home he attended the classes of Materia Medica and Pharmacy and Chemistry in the Edinburgh University.

In 1845 he returned to India, and was called upon to do military duties with a native regiment for a short time.

In 1846 he was appointed Professor of Chemistry and Materia Medica to the Madras Medical School, of which school he became, in 1849, superintendent. When in that position he published a Manual of Chemistry for the use of the students, a second edition of which was called for in 1852.

He forwarded to the great Exhibition of 1851 specimens of Fixed Oils which he had prepared, and for which he had the honour of having awarded to him by the Commissioners one of the Medals of Merit of the Exhibition.

On promotion to the superintending surgeon grade, he ceased by the existing rules of the service to be longer attached to the Medical School, and discharged the duties of this office in the above capacity till his health compelled him to leave India in 1854.

During his residence at Madras he devoted much time to several institutions, among which may be mentioned the Military Male Orphan Asylum; the Monegar Choultry, an institution for the medical treatment of the native poor, of which he was secretary and treasurer for seven years; and the Madras Medical Fund, of which he was secretary for four years.

For his very valuable services in these capacities, he had the honour of receiving, on his retirement from the service, the thanks of the Government and of the Boards of these institutions.

Since 1854 he resided chiefly at Edinburgh. He was elected a Fellow of the Society in 1868, and died suddenly at Edinburgh on Sunday, 18th January 1880, at the age of 76.

William Lassell. By the Rev. T. R. Robinson, D.D., F.R.S., Armagh Observatory.

William Lassell belonged to a class of men which is (as far as I know), peculiar to these Islands; men who, while carrying on commercial or manufacturing business with energy and success, join to it higher pursuits, seeking recreation in devotion to some department of science, some doing this at much sacrifice of time and labour, and frequently at a princely expenditure of money, and often rewarded by results of the highest importance to knowledge. Such persons deserve all honour, and of such none more than the subject of this notice, whose services to what may be called Optical Astronomy were so great as fairly to entitle him to rank with Sir William Herschel and Lord Rosse. He first became known to the astronomical world in 1840 by his description of a Newtonian of nine inches aperture, which he mounted on an Equatorial of his own contrivance at his residence near Liverpool. The specula were polished by hand, but must have been of surpassing light and definition, for he saw with it (having no previous knowledge of the star's existence) the sixth star of the trapezium in Orion, which the elder Struvè had failed to detect with the renowned Dorpat *Achromatic* nine and half inches aperture!

With this instrument he did good work for some years, till the success of the late Lord Rosse, in figuring specula of very large size by machinery, made him wish for a larger telescope. After visiting Parsonstown and studying Lord Rosse's work, he constructed a two feet Newtonian by processes which he has described in the "Astronomical Society's Memoirs" (vol. xviii.) with singular precision and clearness of detail. He was far from copying Lord Rosse's method (and his mode of forming the alloy was objectionable, when arsenic was used, even dangerous), and although his machine was found by himself and also by Warren De La Rue to be imperfect, yet his minute observation of even the most trifling facts and his intelligent appreciation of their bearings on the result, enabled him to obtain in this instance also an admirable telescope; though ultimately he used another machine whose action nearly resembled Lord Rosse's.

This telescope showed seven stars in the Orion trapezium, which

from my acquaintance with that object in Lord Rosse's six feet, I consider a real feat. With it he discovered the obscure ring of Saturn, his eighth satellite, two satellites of Uranus, and one of Neptune, besides making a number of valuable observations on the physical aspects of the Planets.* In 1850 he applied to the specula of this telescope a system of lever counterpoises intended to support their weight laterally and prevent any of the distortions which he thought the usual hoop supports might produce at low altitudes. But it may be questioned whether they were less likely to do harm than the hoop, which acts very well. Latterly, dissatisfied with the smoky atmosphere of Lancashire, he established this telescope at Malta, where he observed with it for a year. The wonderful clearness of the sky excited in him a desire for yet more powerful optical means, and he constructed another Newtonian of four feet aperture, which he has described in the "Memoirs of the Astronomical Society, vol. xxxvi." Its equatorial is similar to the mountings of the former telescopes, but it would not be sufficient for the present demands of Astronomy, though it met all his requirements then. Yet it was a noble piece of engineering (and its low cost as compared with that of more recent equatorials is not unimportant). The tower which carries the observer is well worthy of notice. It was erected at Malta in 1862, and Lassell worked with it for four years, when failing health compelled him to renounce open air observations, and to return to England. In proof of the excellence of this telescope it may suffice to quote the words of Otto Struvè :—

"The way in which it showed the satellites of Uranus and Neptune gave me a very high idea of the excellence of this telescope. . . . . Several double stars which I examined convinced me that in respect of sharpness of image Mr Lassell has obtained a remarkably favourable result; χ Aquila 7 and 8 magnitudes and 0·6 apart, were clearly separated in dark night. . . . . And the images were equally perfect at all altitudes."

The observations at Malta occupy a large part of vol. xxxvi. of "Astronomical Memoirs," and are of great value, in particular those of Nebulæ, with their accompanying illustrations; for the correctness

* Some of these were simultaneously observed by Bond in America, with the Harvard fifteen inch aperture Achromatic.

of several I can vouch from my acquaintance with them in the Parsonstown six feet.

It is greatly to be regretted that this noble telescope was not acquired by some national Observatory. Lassell was willing to dispose of it to the Victoria authorities, who were thinking of establishing a great telescope at Melbourne; but an unhappy misunderstanding prevented them from accepting his offer. After a few years the instrument was broken up, and its materials sold. On his return to England he re-erected the two-feet Equatorial and continued to observe with it till his sight failed him. He died October 5, 1880, in his 82nd year. He was not less active as a writer than as an observer. In the Royal Society Catalogue his name occurs seventy-seven times, and there is scarcely one of those papers that does not contain valuable information. And his work was well appreciated. The University of Cambridge conferred on him the degree of LL.D. He was a member of many celebrated scientific Societies, and was President of the Astronomical Society, whose gold medal he received; he received also a royal medal from the Royal Society of London.

I conclude this notice by stating that my intercourse with him gave me the impression that he was a good and noble-minded man of high purpose, and utterly unclouded by any of that jealous and contentious spirit which too often darkens scientific life.

Maurice Lothian. By Sheriff Hallard.

Maurice Lothian, formerly Procurator-Fiscal of this county, died at St Catherine's, in the neighbourhood of this city, on 15th July last, in his 85th year.* He became a Fellow of the Royal Society in 1869, having then for some years outlived that critical moment in old age mentioned by the Psalmist. For him, as for others, our diploma was one of the crowning honours of an active and well-spent life.

* Born in the end of the eighteenth century, he was wont to tell of a family incident which connected him with its beginning. His grandfather was in the Porteous mob. Disguised in his wife's clothes, this ancestor took his share in the business transacted in the Grassmarket on that memorable night, came home before dawn, resumed his male attire, went down to Leith, took ship, and never was heard of more.

A shrewd lawyer, an effective speaker for a popular audience, keen in his aims, fertile in resources for attaining them, he rapidly achieved that local notoriety which some slight change of circumstance and a higher ambition might perhaps have developed into fame. But he was content with that pre-eminence which he quite irresistibly won in his own surroundings, with the admiration of some and the respect of all. His busy professional and official life left him little leisure to cultivate literature and science, much as he, from a popular point of view, was able to appreciate both, though he recoiled somewhat from the audacities of modern thought. Many years ago he contributed to the eight edition of the Encyclopedia Britannica an article on "Master and Servant," a short treatise, clearly and vigorously written, with reliable and sufficient information upon the law of that important subject as it then stood. Whenever the cause of morality and religion seemed to invite his services, Maurice Lothian stood forth as an energetic and impressive lay preacher. In that connection one is apt to picture to one's self that fine head and presence which we all remember.

For many years he was one of the leading directors of an institution which, among other things, aims at popularising some of the results of scientific enquiry. As a vice-president of the Philosophical Institution, Maurice Lothian will be long remembered. We desire that as a Fellow of the Royal Society of Edinburgh he may not be forgotten.

Mungo Ponton, W.S.

(*From materials chiefly supplied by Mrs Ponton.*)

Mungo Ponton was born at Balgreen, near Edinburgh, in the year 1801. He was educated for the legal profession, and, in due course, became a Writer to the Signet. He was one of the founders of the National Bank of Scotland, and it was in his office that the plans were matured for the establishment of that institution. He held the office of legal adviser to the Bank, and subsequently that of secretary. The strain of the double duties thus imposed on him proved too much for his strength, and a serious attack of illness compelled him to retire from active life while yet comparatively a young man. Since that time he continued more or less of an invalid, but his

intensely active mind found congenial occupation in scientific and literary pursuits. He discovered the peculiar effect of light on gelatine when treated with the bichromate of potash, which was afterwards practically applied in the autotype process. Indeed, it is upon the sensitiveness of this salt to light, under certain conditions, that all the processes of permanent printing of the present day are based; and this discovery of his consequently marks the commencement of an era in photography, and renders his name as closely connected with the history of that art as are those of Niépce, Daguerre, and Talbot. It was in 1839—the very year in which the wonderful process of Daguerre was announced to the world—that Mungo Ponton called attention to bichromate of potash as a photographic agent, and described a process—the foundation of every subsequent permanent printing process—whereby, through that agent, durable impressions on paper might be produced. This discovery, which had been first announced to the Scottish Society of Arts on 29th May 1839, was given to the world in the Edinburgh New Philosophical Journal, vol. xxvii., 1839, under the title, "Notice of a Cheap and Simple Method of Preparing Paper for Photographic Drawing."

In December 1838, he obtained the Honorary Silver Medal of the Society of Arts of Scotland, "for the ingenuity displayed by him in the Model and Description of his Improved Electric Telegraph; read and exhibited 10th January and 20th June 1838, when Mr Ponton presented his elegant model to the Society, to be placed in their Museum."

His inventive turn of mind led him to take a great interest in the proceedings of the Scottish Society of Arts. He was admitted a Fellow of that Society in 1833, and shortly afterwards was made Foreign Secretary. He was elected their Vice-President in 1837, and again in 1844. He also acted for some time as editor of their Transactions. His first scientific paper, "On a Method of increasing the Adhesion of the Wheels of Locomotives to the Rails" was communicated to that Society in 1837.

He was the first who employed the photographic method for registering automatically the fluctuations in thermometers and other instruments, and for this invention he received also the Silver Medal of the same Society in 1845.

On the 20th of January 1834, he was elected a Fellow of the Royal Society of Edinburgh, and in December preceding he contributed a paper to our Proceedings (vol. i. p. 31), "On a New Species of Coloured Fringes developed between certain pieces of Plate-Glass, exhibiting a new Variety of Polarisation, and a peculiar Property which renders them available for the purposes of Micrometry." The author found that the fringes presented the appearance of three rectilinear bands, each consisting of black, white, and coloured stripes, but the central band was afterwards found to be composed of two united into one. There is thus a band for each of the four surfaces of the plates, and these bands possess a property which he thought might be available for micrometry. When the surfaces of the plates are parallel, two of the bands are united into one at the centre; but if a film be introduced between the plates, so as to cause them slightly to diverge, the two bands in the centre will be separated, and move laterally from each other, still preserving parallelism. A film, $\frac{1}{500}$ of an inch in thickness, causes the central bands to separate to the distance of an inch, so that every $\frac{1}{20}$ of an inch of separation is equivalent to $\frac{1}{10,000}$ of an inch in thickness.

On the 16th of January 1837, he read a paper to our Society on the condition of the earth, as it is first described in the Mosaic account of the creation. In this paper, he held that in a philological point of view, the most correct translation of the words rendered "without form and void," is *immeasurable and imponderable.* He seemed to lean to the opinion that the strata of the earth containing organic remains were formed during the very epoch embraced in the Mosaic narrative, and that the primitive condition of the earth was properly gaseous. In this connection, it may be mentioned, that his theoretical knowledge of music was uncommon, and that he arranged to music a metrical translation of the Psalms from the original Hebrew.

Having proposed the micrometer above described, Mr Ponton subsequently devised a photometer, which he described in a paper read to this Society on the 14th of March 1856, and published in our Transactions (vol. xxi. p. 363). The principle of this instrument consisted in comparing lights of different intensities by judging of the relative brilliancies of two definite surfaces when illuminated from two sources of light to be compared, care being

taken to have the illumination homogeneous. This condition was secured by causing the light from each source to pass through a combination of blue glass and blue paper steeped in a solution of sulphate of copper. This combination of glass and paper was enclosed in two tubes. If the apertures were equal, the blue spots seen on admission of a source of light were exactly of the same tint and intensity; but if one of the apertures were a little smaller, one spot not only seemed darker, but of a slight difference of colour. This peculiarity, when combined with a definite modification of the aperture of the tube next the source of light to be compared, enabled the observer to determine gradations of light with fully more exactitude than the method of equal shadows.

Mr Ponton was much occupied with the laws of chromatic dispersion, and read papers on that subject at the meetings of the British Association held in 1859 and 1860. At the latter meeting he also read a paper "On the Laws of the Wave-Lengths corresponding to certain points in the Solar Spectrum." Indeed, it is a remarkable circumstance, that at the time of his death, notwithstanding his advanced age, he was engaged in constructing an instrument for making apparent to the eye the different lengths of the waves of light emanating from two differently coloured media.

In addition to the scientific papers enumerated, he wrote several treatises. His most important work is entitled "The Beginning, its When and its How."

He endured his protracted affliction with exemplary patience, and endeared himself to all who knew him by his cheerfulness and thorough kindness of disposition.

It was on the 3d of August 1880 that Mungo Ponton, who will ever be remembered along with Daguerre and Fox Talbot, as one of the fathers of photography, passed away.

THOMAS KNOX. By the Hon. Lord Shand.

Mr THOMAS KNOX was born at Greenlaw in Berwickshire in 1818. At an early age he left his father's house and came to Edinburgh, where he was apprenticed as a draper. Soon after having completed his apprenticeship he went to Dundee, where he remained for some time as an assistant in an extensive warehouse. It was there he

gave evidence of that public spirit which was so conspicuous through life, and where the foundation of that career of usefulness for which he was distinguished was laid. At that time the hours of shopmen were excessive, and impressed with the evils of this, he, in union with others, inaugurated the movement for shorter hours. It was at a meeting of young men that Mr Knox set himself to expose the bad effects of protracted hours of labour, and to point out the importance of intellectual improvement of the class interested. Before he left Dundee his gifts as a public speaker attracted attention, while his aspirations after mental culture and social reform secured for him the position of a trusted leader among the young men with whom he associated. After a few years spent in Dundee, he returned to Edinburgh, and ultimately commenced business as a partner in the well-known firm of Knox, Samuel & Dickson. Mr Knox was a man of remarkable strength, both mentally and physically, and there were few public men better known or more generally respected among his fellow-citizens. His appearance was commanding; he had fine features, an open frank countenance, a high forehead and dark expressive eyes which gave an impression of intense earnestness to all who met him. He was distinguished by a breadth of thought and enthusiastic attachment to every movement that aimed at the moral, educational, and social elevation of the people, and he was attracted to almost every platform which sought to correct public abuses or lend a helping hand to the struggling and helpless. There was at the same time a geniality of feeling and kindliness of disposition, stirred by generous impulses, which secured for him a hearty welcome among all classes. As a politician he belonged to the advanced Liberal or Radical section of reformers, but he was at the same time tolerant of the opinions of those who differed from him, whether Whigs or Conservatives. As a sanitary reformer he was a fellow-worker with Dr Begg, Dr Guthrie, Dr James Cowan, and latterly with Dr William Chambers, who found in him a hearty coadjutor in carrying out the grand scheme for the improvement of the city, by substituting open well-aired streets for ill-ventilated and confined lanes and closes. In order to the enterprise for that object being carried out, a large amount of preliminary education was necessary to prepare the public mind. With one or two other social reformers, Mr Knox explored the slums and dark places of the city by day and night, and by the

use of his pen he laid bare the true state of matters, by which the citizens were taken by surprise. The exposure which he thus made, by speeches and pamphlets, and through the columns of the press, were the necessary precursors of the City Improvement Act. It was the explorations carried on by him and others among the masses crowded in the lowest localities of the city which also paved the way for the formation of the Association for Improving the Condition of the Poor,—an association which has for a number of years been the means of relieving great distress amongst the deserving poor. The old town was divided into districts, and the sad truth ascertained, by personal visitation, regarding the depth of misery and immorality in the city slums. The result of their labours was to produce a series of pointed and striking articles in the daily press, and also a report of the most melancholy and startling character, and as previously stated these were followed by the formation of the above Association. No sooner had the Improvement Act become operative than Mr Knox cast about for other fields of philanthropic effort. His free winter dinners for the street Arabs of the city, which have gladdened many a half-starved child, and his warm and enthusiastic interest in the Edinburgh Industrial Brigade and the Mars Training Ship as schools for discipline and moral and industrial education, for several years engaged very much of his attention.

As a temperance reformer he was well known throughout Scotland, and the practical results of his labours are to be seen in several clauses of the Forbes Mackenzie and the Public House Amendment Acts. His fearlessness and utter disregard of personal consequences in the proclamation of the truth and exposure of local abuses brought him enemies and detractors amongst those whose personal interests were affected; but, besides the approval of a good conscience, he never failed to secure the trust and confidence of his fellow-citizens, who recognised the noble and generous motives which inspired him.

In his latter years the influence of Mr Knox was powerfully felt in the educational world. The interest and labour which he manifested, in conjunction with the late Mr James Duncan and Lord Provost Boyd, while each in their time were Master of the Merchant Company, were largely instrumental in moulding the educational system as realised in the Merchant Company Schools, which have

proved so successful. Again, so far back as about twenty years ago, he inaugurated an agitation by delivering speeches and publishing pamphlets on the necessity for the introduction of temperance teaching into school books. This proposal was at first treated as too Utopian to be seriously entertained; but before he died he was privileged to see Dr Benjamin Richardson's Temperance Manual largely introduced into many of the public schools, while temperance lessons were being introduced into the school books published by Messrs W. & R. Chambers, Collins & Son, Nelson & Sons, and other noted publishers.

The institution which had the benefit of a large share of Mr Knox's interest and effort during the last few years of his life was the Watt Institute and School of Arts, the earliest of the Mechanics Institutes founded in the United Kingdom. He was appointed Hon. Treasurer in November 1876, and since that time a complete revolution has been effected in the interesting history of the School. The time and labour which he gave in supporting and co-operating with Lord Shand, the President of this People's College, in efforts to extend the usefulness of the school amongst the industrial classes it would be difficult to overestimate: the result was an accession of students in increasing numbers in a degree perhaps unprecedented in the history of any educational institution. Having regard to the general interest taken in the School at the present time by all sections of the citizens, it may be mentioned that the number of students in 1875–76 was 1098; in 1876–77, 1404; 1877–78, 1977; 1878–79, 2185; and 1879–80, 2375. Thus in four years the increase was 1280. In that short period the attendance was more than double, and nothing tended to this result more powerfully than Mr Knox's constant attendance at the classes in the evening when his business labours were over, and his kind words of encouragement to the students. It is an interesting fact that the last few hours of Mr Knox's life were devoted by him to this institution. Before retiring to rest on the night of his death, he wrote out the draft of the Annual Report, in which he made an earnest appeal that the directors might be supported in their endeavours, by means of a union with the Heriot Trust, not only to maintain the School in a state of efficiency, but to extend it greatly, so as that it should become a People's College for Technical Education, really worthy of

the nation and the metropolis. He died on the 4th of December 1879, in the 61st year of his age, having devoted the best part of his life in earnest endeavours to promote the welfare of others.

Lord Ormidale. By the President.

Robert Macfarlane, a judge of the Court of Session, under the title of Lord Ormidale, died on the 2d of November 1880, in his seventy-ninth year. He was in many respects a remarkable man, and his life had elements of interest and variety apart from his professional success. Vigour of thought and force of character were the principal features which distinguished him, and these enabled him, through many changing scenes and some vicissitudes, to assert a foremost rank at the Bar and on the Bench.

He was born in Glen Douglas, on Loch Lomond, on the 30th of July 1802, among some of the grandest and most beautiful scenes of the Scottish Highlands. Nor were the traces of such a birthplace without a reflection in his character. The quick, ardent, intense enthusiasm which marked the man, were the natural fruit of a boyhood spent by mountain and flood; and the cloud and sunshine flitted across his impressionable spirit, as he must have seen them pass over his native hills.

He attended the University of Glasgow in the four sessions from 1816 to 1819, and then came to Edinburgh. Shortly afterwards he went on a voyage to the West Indies, in connection with the affairs of a relative, and after a short residence in Jamaica he spent four or five months in the United States, before returning to this country.

Having on his return resolved to prosecute the legal profession, he became bound as apprentice to Mr James Greig, W.S. In this occupation he was associated with two men who were afterwards very eminent in their respective careers, and very distinguished members of this society. One was the late Lord Neaves, one of the most brilliant of our body, and the other our late lamented Treasurer, Mr David Smith, the loss of whose invaluable services we so deeply deplore.

On finishing his apprenticeship, Mr Macfarlane resolved to enter the body of Writers to the Signet, and for more than ten years, from 1827 to 1838, carried on business in that capacity, as a

member of the firm of Mackenzie & Macfarlane. He passed at the Bar of Scotland in 1838, thus commencing his career as a barrister at the age of thirty-six,—12 or 14 years later than the average age of entrants to the Faculty of Advocates. Such an experiment is always hazardous, for all pursuits require a period of initiation; and the advantages of experience are usually more than counterbalanced by the absence of the elasticity of youth, the formation of confirmed habits of thought, and the necessary disparity between the age and the professional standing of the man. But Mr Macfarlane's energy, industry, and knowledge enabled him to surmount without an effort difficulties which so often prove fatal; and he was very quickly abreast of the general body of well-employed counsel. This position was rapidly gained, and firmly maintained and increased, and his previous legal training had been so thorough, and his knowledge of the practical application of law so complete, as to give him many advantages in the field. He was at one time the best employed junior in the Parliament House. As a counsel in jury trials he was eminent and successful, a department in which his natural sagacity and extensive knowledge of men, and of the springs of action, came to his aid with great effect. He had, in 1837, before entering the Faculty of Advocates, published a work on "Jury Practice," and he followed this up in 1841 by an important volume of "Reports of Cases tried by Jury," and in 1844–49, in conjunction with Mr Thomas Cleghorn, he published a well known treatise on "The Forms of Issues in Jury Trials."

In 1853 Mr Macfarlane was appointed to the important Sheriffship of Renfrewshire, a county, the judicial affairs of which he administered for nine years with great efficiency and popularity. He was elevated to the Bench in 1862, by the title of Lord Ormidale, remaining twelve years in the Outer House, and removing in 1874 to the Second Division of the Inner House.

On the Bench he more than maintained the reputation he had vindicated at the Bar. His conscientious labour, thorough knowledge of business, and clear common sense, were qualities which he combined with a complete mastery of all branches of the profession. In legal dialectics he engaged sparingly, fixing his attention exclusively on the practical questions and interests in the case immediately before him, and throwing aside with unusual facility

collateral and adventitious surroundings. No judge ever commanded more completely the confidence and respect of the profession. On the Bench his previous training behind the Bar came to be of material assistance, as it assured practitioners of the familiarity of the judge with details with which the Bench and Bar are not always conversant. Accordingly, while he sat as a single judge in the Outer House, his Bar was popular, and his judgments, carefully considered, commanded a large measure of confidence; while his short but efficient career in the Inner House was one of unbroken ability and power. He was vigorous to the last, although on the verge of fourscore years. Neither his intellect nor his athletic frame indicated any abatement of his strength when he last appeared on the Bench, but a few weeks before his fatal illness commenced. He has left behind him that inheritance for which all honourable aspirants after forensic distinction strive, a reputation for judicial ability and integrity which will be long remembered.

Lord Ormidale married a daughter of his friend, Mr Greig. He survived her many years, and has left a large family. In private he was a warm-hearted, genial, and pleasant companion, of a kindly, generous nature, indulgent to error, but intolerant of meanness or deception. His hot Celtic blood was easily quickened by anything like injustice or oppression; but even just resentment did not long retain its hold on him. Kindly and generous, he was a firm friend, and a sagacious, as he was an experienced, counsellor. Although he had reached an age beyond the usual limits of life, no one ever associated with the impulsive and ready vigour of his thoughts and his demeanour the decrepitude of age. His was a useful as well as a successful life to the end: and while the public gratefully remember, and deeply regret the loss of so valuable a servant, many a friend will long think, with a heavy heart, that his animated features, cheerful voice, and ready sympathy, will meet them no more.

For myself, I render this slender tribute to his memory under a sense of a grave personal bereavement. I sat side by side with him for six years, and no man could have had a more loyal and trustworthy colleague, or a truer, more trusted, or more attached friend.

Dr William Sharpey. By Dr Allen Thomson.

Dr William Sharpey was born at Arbroath in Forfarshire on the 1st of April 1802. His father was an Englishman, and belonged to Folkestone in Kent; but in the year 1794 he migrated to Arbroath, and married Mary Balfour, a native of that town. Mr Sharpey having died shortly before the birth of his son William, his widow was afterwards married to Dr William Arrott, a medical practitioner of Arbroath, in whose family the subject of this notice was brought up.

William Sharpey's education was carried on up to the age of fifteen at the public school of Arbroath. In November 1817 he entered the University of Edinburgh, as a student in the Faculty of Arts, attending the Greek and Natural Philosophy classes.

In 1818 he commenced his medical studies in the University and the Extra-academical School of Edinburgh; and in 1821, at the early age of nineteen, he obtained the diploma of the Edinburgh College of Surgeons. He then studied anatomy for some months at Brooke's School in London, and subsequently passed nearly a year in surgical and medical study at Paris. Returning to Edinburgh in the end of 1822, he graduated in medicine in August 1823, his printed inaugural dissertation bearing the title "De Ventriculi Carcinomate;" after which he again spent some time in Paris in attendance on the Hospitals and on classes at the Garden of Plants.

From 1824 to 1826 his plans appear to have remained undecided; but having finally resolved to devote himself to anatomical and physiological pursuits, for which he had long had a predilection, he was desirous to improve himself still more by foreign travel, and especially to make himself thoroughly acquainted with the system of instruction in the Universities of Italy and Germany. With this view he spent more than fifteen months in Switzerland, Italy, Austria, and Germany, often journeying on foot with knapsack on his back, and storing up in his wonderfully tenacious memory that fund of information, anecdote, and incident which surprised and delighted those who heard him in after life narrate his travels.

Reaching Berlin in the autum of 1828, he gave his whole time during nine months to the careful dissection of the human body and the study of scientific anatomy, in which he had the inestimable

advantage of the friendship and assistance of the learned and genial Rudolphi.

On his return from the Continent in the autumn of 1829, Dr Sharpey established himself in Edinburgh, and was for a time engaged in anatomical researches. In 1830 he became a Fellow of the College of Surgeons there, upon which occasion he presented a probationary essay, "On the Pathology and Treatment of False Joints." In the summer of 1831 he again spent some time in Berlin for the purpose of collecting specimens to illustrate the course of lectures on anatomy, which it was his intention to deliver in the following winter. After embarking in this enterprise he continued to give systematic instructions as a teacher in the extra-academical School of Edinburgh, during five years, or from 1831 to 1836; and while his success as a lecturer was evinced by the large and progressive increase in the number of his pupils, his scientific reputation both at home and abroad had advanced in a still greater degree by the known care and accuracy of his observations, and the extent of his scientific knowledge.

In the summer of 1836 the Chair of Anatomy and Physiology in the then University of London having become vacant by the resignation of Dr Jones Quain, and the authorities and leading medical professors of the university being desirous to give greater prominence than previously to the teaching of Physiology and Physiological Anatomy, Dr Sharpey was, in the month of July, selected to fill the chair; it being determined that while he, as Professor of Anatomy and Physiology, should give full instructions in Physiology and in minute Anatomy and the structure of the Viscera, his colleague, Mr Richard Quain, should, as Professor of Anatomy, undertake the more purely descriptive and practical anatomical department. There was thus established in London for the first time the full and systematic teaching of Physiology, which had previously been only imperfectly treated as an appendage to the courses of Anatomy.

Dr Sharpey applied himself to the performance of his new duties with all the care and diligence which was to be expected from so conscientious a teacher, with a range of knowledge of his subject rarely equalled, and with powers of exact observation and critical judgment of the highest order; so that it was not to be wondered

at that, as he soon became more closely identified with all the interests of the institution to which he belonged, his influence increased in proportion, and he came to be regarded not merely as one of the best teachers of his department, but as one of the highest authorities in biological science.

Dr Sharpey continued to perform the duties of his chair during the long period of thirty-eight years, maintaining to the last the same scrupulous care in the preparation of his lectures and the performance of all his academic duties which had distinguished the earlier and more vigorous parts of his career. And all his pupils, many of whom occupy very high places in science and medicine, acknowledge with pleasure their debt of gratitude to their teacher, not alone for the exact and solid information which they derived from his instructions, but also for the scientific spirit and love of truth which he endeavoured to instil into their minds.

Dr Sharpey's wide range of information, together with his remarkably wise and fair judgment, were such as to inspire great reliance on his opinion, and naturally led to his being called upon to take an active part in the management of other scientific institutions of the metropolis.

In 1840, when the London University obtained its charter to grant degrees, he was appointed one of the examiners, and he retained that office during the unusually long period of twenty-three years. He was at a later period a member of the Senate of the University. During fifteen years he was a member of the General Medical Council of Education and Registration. He was a trustee of the Hunterian Museum of the Royal College of Surgeons, and a member of the Science Commission which met under the presidency of the Duke of Devonshire from 1870 to 1875. And it need scarcely be said that in the affairs of these several bodies, as in all others with which he was concerned, his extensive knowledge, clear sagacity, and sound judgment aided greatly the deliberations of those with whom he was associated, and contributed to the advance of science and the promotion of measures of public utility.

But the body with the management of which, next to University College, Dr Sharpey was most closely connected, was the Royal Society of London, which he joined as Fellow in 1839, and of

which he was one of the secretaries from 1853 to 1872. Those who were most fully acquainted with the affairs of the Society know best the anxious care and judicious labour which he bestowed upon its business, and readily distinguish the mark of his able assistance in the promotion of various measures having important relations to the interests of the Society and the advance of science which were the subjects of deliberation during his tenure of office.

Dr Sharpey became a Fellow of the Royal Society of Edinburgh in 1834. He was member of many other societies in this country and on the Continent; and he received the honorary degree of LL.D. from the University of Edinburgh in 1859.

Dr Sharpey was by no means a copious writer, nor could he be regarded as the author of many new discoveries, yet it is universally acknowledged that great value is to be attached to his original observations and the productions of his pen.

He never wrote out his lectures fully, but made use only of jottings on small slips of paper, and only two or three of his introductory lectures have been published in the medical journals.

During the time of his residence in Edinburgh, or from 1829 to 1836, he was actively engaged in original research; and among the earliest and in one sense the most important of his observations were those relating to Ciliary Motion, first described in his paper "On a Peculiar Motion excited in Fluids by the surfaces of Animals" (*Edin. Med. and Surg. Journ.*, 1830, vol. civ.), and which formed the basis of his very able and complete article "Cilia," which appeared in the *Cyclopædia of Anatomy and Physiology* in 1836. It is true that Dr Sharpey, as he afterwards found, had been anticipated in several of his observations, and further, that, from the want of sufficiently high magnifying powers in his microscope, he failed to detect the actual existence of cilia in the larvæ of Amphibia in which he had observed the motions,—a discovery which was made by Purkinje and Valentin in 1834,—but it cannot be doubted that, by the numerous original observations which Dr Sharpey described in his earlier paper, he was the first to point out distinctly the general prevalence of ciliary motion among animals, and the important relations of its phenomena to respiration and some other functions. The article "Cilia," as also that of "Echinodermata," which in 1837 he contributed to the same

Cyclopædia, both contained a large amount of original matter, and gained for Dr Sharpey a high reputation as a scientific observer and writer.

In 1833 Dr Sharpey gave in the "Edinburgh New Philosophical Journal" an account of Ehrenberg's Researches on Infusoria. In 1834 he took part in the proceedings of the British Association for the Advancement of Science which met at Edinburgh, and contributed a paper founded on his own observations on the peculiar distribution of the arterial vessels in the Porpoise.

He delivered the "Address in Physiology" at the Thirtieth Annual Meeting of the British Medical Association held in London in 1862; and in 1867, as president of the Biological section of the British Association at the Dundee meeting, he delivered an address in which, as in the one previously mentioned, he ably reviewed the progress of Physiology, more especially as regards the application of exact methods of research to the solution of physiological problems.

But Dr Sharpey was extremely fastidious as an author, and though his style was clear and his language eminently appropriate, yet he shrank from frequently appearing in print: and accordingly much of his original observation and thought on scientific subjects, though involving laborious research, was made known by him only through his lectures, or was published in a more or less fragmentary form in connection with such systematic works as Baly's translation of Müller's Physiology and the later editions of Quain's Anatomy. In the first of these works it is well known that the excellent translator, who was a distinguished pupil of Dr Sharpey's class, derived much assistance in his labours from his teacher, and several notable additions were made to the work by contributions from Dr Sharpey's pen. Among these one of the most important is that, in the modest form of a note, in which he gave an account of original observations made by himself on the structure of the uterine glands and membrana decidua.

In 1843–46 Dr Sharpey published as joint editor with Professor Richard Quain the fifth edition of Dr Jones Quain's Elements of Anatomy, which, from the amount of new matter introduced and changes made by the editors, assumed almost the character of a new work. In this edition the General Anatomy was entirely rewritten

by Dr Sharpey, and this part has ever since been looked upon as a standard work on the subject of which it treats, containing the record of a large number of original observations on the minute structure and growth of bone and on many other topics. The anatomy of the brain and heart, of the organs of respiration and voice, of digestion and reproduction, were also from his pen. With the three subsequent editions of this work Dr Sharpey remained connected as one of the editors till the time of his death.

Up to the age of sixty-nine or seventy years Dr Sharpey retained most of the vigour of his earlier life. But about the year 1871 some signs of advancing age showed themselves, and more especially the rapid increase of cataract, affecting both eyes, began to interfere with the easy and efficient performance of his official duties, and led to his retirement from the secretaryship of the Royal Society in 1872, and from his professorship in University College in 1874. His blindness was only partially remedied by the extraction of the cataractic lens of one eye in May 1873, and of the other in October 1876. About the same time Dr Sharpey became subject to attacks of bronchitis from any unusual exposure to cold. One of these had nearly proved fatal in the winter of 1878, and he at last succumbed to an attack of the same malady on the 11th of April of the present year (1880), ten days after he had completed his seventy-eighth year. He was buried in the Abbey Graveyard of Arbroath, his native town, on the 17th of April.

In 1869 the friends and former pupils of Dr Sharpey, being desirous of showing their regard for him and establishing a permanent memorial of his services to University College and to science, raised by subscription a sum of money for endowing a "Sharpey Memorial Scholarship" in connection with University College, and for presenting to the college his portrait in oil and a marble bust.

In 1872 Dr Sharpey made over his large and well-chosen biological library to University College, and at his death he bequeathed from the small property which he left a sum of £800 to increase the endowment of the Scholarship in Physiology.

Upon his retirement from his professorship in 1874, Mr Gladstone's government accorded Dr Sharpey an annual pension of £150 on account of his eminent services as a public teacher and man of science.

Looking back upon the career of our much esteemed fellow, we have first to remark the characteristic caution with which he abstained from entering upon any active or responsible sphere of exertion till he had attained his twenty-eighth year, and the care with which he prepared himself by long continued literary and scientific study in this and other countries for the duties of his after life.

In his work as a scientific investigator and systematic writer, there is everywhere apparent a scrupulous accuracy and full knowledge of his subject, a clearness of statement and appropriateness of language, a critical acumen and soundness of judgment which have given high and lasting value to his productions.

In the administration of the affairs of the various public bodies with which he was connected, Dr Sharpey's wide range of knowledge, his unbiassed judgment and strict impartiality, while they gave weight to his opinions and suggestions, contributed in a remarkable degree to the efficiency and usefulness of his services.

It was however especially as a teacher that the influence of Dr Sharpey's superior mental qualities was most conspicuous. Devoting himself with the utmost diligence and care to the perfecting of his public instructions, he was uniformly listened to with the closest attention, and regarded as the highest authority in his department; and the effect of his teaching was further enhanced by the feeling of friendly attachment, amounting almost to filial affection and reverence, which was inspired in the minds of his pupils by his uniform kindness, justice, and candour.

In private life, while Dr Sharpey was universally admired for the extent and accuracy of his acquirements and respected for the soundness of his judgment, he was not less esteemed and beloved for the gentleness of his disposition, the kindness of his heart, and the geniality of his nature. His powers of memory, naturally good, were carefully cultivated by the systematic turn of his mind, and strengthened by exercise. His friends remember with delight the readiness with which in the course of conversation he could call up a desiderated quotation, or supply a fact on some doubtful point in history, philosophy, or science, or tell humourously some anecdote which was equally apposite and amusing. He had not a single enemy, and he numbered among his friends all those who ever had the advantage of being in his society.

The following Communications were read:—

1. On a Simple and Accurate Method of determining the Longitude of a Place by a Single Observer, without the aid of any instrument for measuring time. By Professor G. Forbes.

2. Stilbite, from Kerguelen's Island. By A. Liversidge, Assoc. Royal School of Mines, Professor of Geology and Mineralogy, University of Sydney. Communicated by Mr J. Y. Buchanan.

I am indebted to the kindness of my friend Mr J. Y. Buchanan, M.A., the chemist and physicist to the "Challenger" expedition for the specimen which forms the subject of this note.

In speaking of the geology of Kerguelen Island, Mr Buchanan thus describes the occurrence of this zeolite (*vide* Proc. Roy. Soc., vol. xxiv. p. 617).

"The horizontal beds which form the mass of the land are basaltic, and vary from 10 to 20 feet in thickness, being generally compact; but, in ascending the hill, beds are met with frequently, which contain large amygdaloidal cavities filled with zeolites, principally analcite and heulandite (stilbite). These minerals are very plentiful in this part of the island, and when rounded by the action of the water they form remarkable white pebbles on the otherwise dark-coloured volcanic sand. Up to the summit the alternation of beds of compact sub-columnar rock of amygdaloid is pretty regular.

"The amygdaloid is of two kinds: in the one the cells are small, very thickly disseminated, and completely filled up by a zeolitic mineral; the other has larger cavities, less thickly spread, and generally only coated with crystals, while seams filled with crystalline matter are also frequently met with. The cavities contain generally analcite; the seams, heulandite" (stilbite).

In quoting the above extract, I have ventured to insert the name stilbite after heulandite, since both names have been applied to the same mineral. Personally, I should call the specimen stilbite, inasmuch as it agrees with the mineral known as stilbite by English

mineralogists both in form and chemical composition, and not with heulandite. It is rather unfortunate that heulandite is known as stilbite by some mineralogists; stilbite is also known as desmine (Breithaupt) by others.

The lower part of the small specimen is in the form of an incrustation of about $\frac{1}{8}$ to $\frac{3}{16}$ of an inch in thickness, from which flat plate-like crystals project at various angles. The lower layer is compact, and presents a mammillated surface where exposed to view, and its fractured edges present a series of small radiate fan-shaped cleavage planes, with a well-marked pearly lustre.

The larger of the projecting platy crystals are about $\frac{1}{2}$ inch long by from $\frac{1}{4}$ to $\frac{5}{16}$ broad, and not more than about $\frac{1}{16}$ inch thick. They are built of plates of more or less imperfectly developed flattened prismatic crystals. This structure tends to impart a sheaf-like appearance so common in stilbite. The crystals are semi-transparent and practically colourless. Parallel to the principal cleavage planes the lustre is strongly marked and pearly; vitreous on the other faces. They are brittle and cleave readily parallel to the brachydiagonal; less readily parallel to the macrodiagonal.

The faces developed in the specimen are the brachy- and macro-pinacoids capped with the planes of the pyramid. The planes of the pyramid and of the macropinacoid are small; the brachy-pinacoids are large; the basal pinacoids, so commonly present, are undeveloped. Hardness about 4.

The specific gravity of the mineral in fragments was found to be 2·24 to 2·25, but when reduced to powder it rose to 2·29, thus showing the presence of sensible cavities.

Before the blow-pipe it exfoliates, intumesces, curves outward into vermicular forms, and fuses to a white enamel, and is decomposed by boiling hydrochloric acid without gelatinising. The lower in-crusting portion of the specimen colours the flame much more strongly yellow, does not intumesce to the same degree, and is decomposed by hydrochloric acid, with the separation of gelatinous silica. It is therefore apparently not the same zeolite as the crystals, but is most probably sphaero-stilbite. I much regret that I had not sufficient to permit a quantitative analysis being made of it also.

ANALYSIS.

	I.	II.	Mean.
Water, . . .	17·42	—	17·42
Silica, . . .	56·46	56·58	56·52
Alumina, . . .	16·28	16·40	16·34
Lime, . . .	8·12	8·01	8·06
Magnesia, . .	·12	·16	·14
Soda, . . .	—	1·76	1·76
			100·24

which corresponds to the usual formula of stilbite. viz. :—

$$Al_2O_3 , 3SiO_2 + \left.\begin{matrix} \frac{5}{6}CaO \\ \frac{1}{6}Na_2O \end{matrix}\right\} 3SiO_2 + 6H_2O .$$

3. On a Simple Form of Selenium Cell, and Experiments therewith. By Prof. James Blyth.

The cell is constructed as follows :—

Take a brass crop-comb of the kind usually worn by little girls. Cut off from it two equal parts, each about 4 inches long. From each part cut out each alternate tooth, and bend round each part in the form of a cylinder, soldering the ends together with hard solder. Take a glass tube about 4 inches long and having a diameter equal to the diameter of the cylinder. Place the brass cylinders upon the glass tube, with the teeth facing each other, and adjust them so that each tooth left takes the place of one which has been cut out, taking care that the teeth do not touch each other nor the solid parts of the cylinder.

Now heat the cylinder in a Bunsen flame to a temperature sufficient to melt selenium—about 220° C—and rub a stick of selenium over the spaces between the teeth, so that each space gets filled with selenium, which will now be in an amorphous condition. To anneal it, place the whole in an air-bath at a temperature of about 150° C for an hour or so, when the selenium will assume a metallic and crystalline appearance. Allow it to cool gradually, and then solder on two copper wires to the solid part of each brass cylinder to serve as electrodes. The cell is now ready for use.

In order to show the action of light on the cell. I placed it over

a glass tube containing a singing flame, and connected it in circuit with a battery of six Grove's cells and an ordinary telephone, or still better a Gower Bell telephone. The note produced by the singing flame was faintly but distinctly heard in the telephone placed in a distant room. It will be readily seen, that, in this experiment, we take advantage both of the heat and light effect upon the selenium, and that the action is increased by the close proximity of the cell to the flame.

If the indiarubber tube carrying the gas to the singing flame be rapidly pinched and let free, the increase and decrease of the flame is instantly indicated by the telephone; and if the pinches are made rhythmically, a corresponding rhythm is heard in the telephone.

The above experiment can also be performed very well by attaching the singing flame jet by an indiarubber tube to one of Koenig's manometric capsules screwed on to an organ pipe. The note of the pipe is then heard in the receiving telephone.

Having obtained a cell which was sensitive to a singing flame, it was an easy step to try if it would be equally sensitive to the variations of the flame of a Koenig's capsule produced by singing and speaking. To test this, I placed the cylindrical cell over the flame, so that the flame was in the axis of the cylinder and exactly opposite the selenium. When the cell was now joined up in circuit with fifteen Grove's cells and a telephone, not only singing, but speaking was distinctly reproduced in the telephone.

This experiment is very remarkable, as it shows that the resistance of the selenium must vary with very great rapidity; otherwise it could not transmit articulation.

Flat cells of the comb form are very easily constructed by simply screwing the combs upon a flat piece of wood, taking care that the teeth do not touch each other. The whole is then heated up to the melting point of selenium, which is then rubbed carefully between the teeth. The annealing is a matter of great importance. It can be done very well in an air-bath, whose temperature can be regulated by a thermometer. During the time the cell should be joined up in circuit with a Wheatstone's bridge, and its resistance carefully tested all through the annealing process. It will be found that the resistance of the cell gradually diminishes with a rise of temperature, and finally attains a minimum, after which it begins to rise

again. At that particular point further heating should be avoided, and the cell allowed to cool slowly. During the cooling the resistance rises, and does not appear to reach its final value till the cell has been some time in use.

It is obvious that what is wanted, to make a selenium cell as sensitive as possible, is to have a long thin layer of it between two parallel conductors forming the electrodes, and so to arrange it, that as great a length of that layer as possible can be brought at once under the influence of the source of light. These conditions are well fulfilled in what may be called the *radial* cell, which consists of a series of brass sectors with very acute angles fixed upon the end of a wooden cylinder, and having narrow radial slits between them. This form is easily made by first fixing a disc of brass about 3 inches in diameter upon the wood, and then cutting it right through by a saw along a series of diameters equally inclined to each other. The odd number sectors are connected by one wire which forms the one electrode, and the even numbers by another wire which serves for the other electrode.

My first supply of selenium running done, I ordered a second, and proceeded to make another cell exactly in the same way as I had made the previous one. This cell, however, when finished, presented some very troublesome and perplexing peculiarities, inasmuch as its resistance during annealing fell very low—to something like 120 ohms—and yet it was almost entirely insensitive to the action of light. This effect is, without doubt, due to some impurity in the selenium, which I hope to detect by a chemical analysis which is being made for me.

The failure to get good selenium led me to think if anything else would serve as a substitute, and the first thing I determined to try was amorphous phosphorus. I took a radial cell and packed the slits full of the phosphorus, and then proceeded to test its resistance in the ordinary way, but was surprised to find that I could not get a balance. This led me to see that the cell itself was acting as a battery, and on trying it directly through the galvanometer, the needle was deflected off the scale. I also observed that the current varied with pressure on the phosphorus; and this suggested to me that it might be made to serve the double purpose of battery and loose contact in the ordinary form of microphone transmitter.

For this purpose, I made a special transmitter, which consists of a shallow wooden box, having a disc of brass in its bottom, to which one electrode is attached. Above this is placed a thin layer of the red phosphorus, and the whole enclosed by very flexible brass plate, bound down round the edges, and having the other electrode attached to it. A mouthpiece is arranged so as to direct the voice against the centre of the thin brass plate. When this transmitter is joined up in circuit with a telephone, singing and articulation are distinctly reproduced. When a battery is included, the sounds come out of the telephone with singular clearness and loudness; and there is also a very remarkable want of any rattling, such as is usual with an ordinary microphone. I have also found that the cell, which is really a form of loose contact, can act as a receiver as well as a transmitter; but my experiments on it in this capacity are as yet incomplete.

4. Dust, Fogs, and Clouds. By Mr John Aitken.

(*Abstract.*)

Since I made my first communication to this Society on Dust, Fogs, and Clouds, most of the experiments have been repeated under different conditions.

Taking advantage of the late extremely cold weather, the apparatus was placed in the open air, and experiments made with it, the temperature of the air at the time being 8° Fahr. The result was the same as at higher temperatures. Cloudy condensation with dusty air; no condensation with filtered air.

The experiment in which dustless gas was burned in dustless air was repeated. The glass jet which was used for burning the gas in the first experiment, being now replaced by a platinum one, as it was thought possible the dust produced when the glass jet was used might be the result of the decomposition of the glass by the heat. Before making the experiment, the platinum jet was highly heated, to cleanse and make it inactive. The result, however, was as before. Dense fogging whenever the gas was lit, and the fogging continued so long as the gas was kept burning.

The experiment for detecting small quantities of dust has also

been altered and improved. Instead of detecting the dust by the cloudy condensation of steam, the saturated air of the receiver was cooled by slightly expanding it. Working in this way, it was found that the dust driven off by heat from a piece of iron wire, the $\frac{1}{2000}$ of a grain gave such an evident and abundant result, that if the $\frac{1}{100,000}$ of a grain of iron could be manipulated the effect would be perfectly definite and decided. This indicates an extremely small size of some of the condensation nuclei. Thousands of particles driven off the $\frac{1}{2000}$ of a grain of iron, and the iron afterwards not perceptibly lighter, indicates almost molecular dimensions. It was pointed out that some of these nuclei may be driven off as gases, which afterwards condense and form nuclei for the vapour to condense upon.

In the first paper attention was called to the composition of the atmospheric dust. It was pointed out that some kinds of dust would have a greater attraction for water vapour than other kinds, and that chloride of sodium dust would probably condense water vapour before the vapour was cooled to the saturated point.

It was shown that there are two distinct ways in which dust acts as a centre of condensation, and causes vapour to condense before it is saturated. The first is the chemical affinity between the dust and the water vapour. The second is the condensing power possessed by the surfaces of some bodies. This power is different in different kinds of matter.

Some experiments have lately been made to see to what extent this attraction of the nuclei for water vapour would cause condensation to take place in air which was not saturated. A little sulphur was lighted, and an open-mouthed glass receiver held over it for a few seconds, and then placed on the table. At first scarcely any effect was noticed, but after a time a haze or fog appeared. The density of this fogging depended on the humidity of the air experimented on. The damper the air the thicker the fogging.

If the inside of the receiver was wetted so as to moisten the air, the sulphur products on entering are a little more evident, and on placing the receiver on the table a thin haze can be seen. After a time, however, this haze gradually grows denser, and at the end of fifteen or twenty minutes the receiver becomes full of a very dense white fog, which remains for a long time. A similar result is got

with chloride of sodium vapour, by highly heating the salt in a platinum tube, and afterwards cooling and drawing the vapour along with air into the experimental receiver.

Many other salts—such as chloride of calcium, bromide of potassium, &c.—when highly heated, have also the power of determining cloudy condensation in unsaturated air. Potassium and sodium, when burned, give also similar results, and the fogging is, in all cases, proportional to the moisture in the air.

Experiments have also been made on a larger scale in a cellar, the air in which was damp but not saturated. The temperature was about 45° Fahr., and the wet and dry bulb thermometers showed a difference of from $\frac{1}{2}$° to 1° during the experiments. A short time after a little sulphur had been burned the whole cellar was filled with a dense white dry fog, which remained for some hours. A similar result was also got by sprinkling some salt over an alcohol flame. The salt dust so produced determined a decidedly foggy condensation in the unsaturated atmosphere.

Experiments were also made by burning sulphur in the open air. When the air is dry, the fumes can only be traced a short distance; but when there is more moisture the condensation is more evident, and in certain conditions of the atmosphere the products of combustion can be seen floating away in the passing air, leaving the sulphur in a pale thin stream of vapour, which gradually increases in size and rolls away in a horizontal cloudy column ten or fifteen feet in diameter, clearly marked out from the surrounding air.

This fog-producing power was shown to be probably due to the affinity which the sulphuric acid, resulting from the combustion of the sulphur, has for water vapour.

It was shown that cloudy condensation may take place without dust particles being present. It will probably take place in a highly supersaturated atmosphere. It will also happen when some substance is vaporised in dustless air and cooled to a temperature far below that corresponding to its tension. When the substance condenses and forms nuclei of condensation for the water vapour, cloudy condensation will also take place in dustless air. When there are gases present which combine and form new compounds, and the temperature is much too low for them to remain as vapours, the molecular strain seems under these conditions to be sufficient to

cause them to condense and form nuclei on which the water vapour deposits. These nuclei may be solid or liquid, and may or may not have affinity for water vapour.

It is concluded from the experiments, first, that as regards cloudy and foggy condensation there is dust and dust. Some kinds of dust have the power of determining condensation in an atmosphere which is not saturated; other kinds only form nuclei in supersaturated air, and from other experiments it is probable that some degree of supersaturation is necessary before some other kinds of dust are active. In highly supersaturated air all kinds of dust will form nuclei and determine cloudy condensation, but in unsaturated air only some kinds are active. This was illustrated by corresponding phenomena in freezing, melting, and boiling. Second, that dry fogs may be produced by some form of dust in the air, such as sodic chloride dust, condensing the aqueous vapour in air which is not saturated. Third, this condensing power or attraction which some kinds of dust have for aqueous vapour explains why our breath and condensed steam dissolve even in foggy weather. Fourth, that as the products of combustion of sulphur determine the condensation of water vapour in unsaturated air, and give use to a very fine textured dry fog, they are probably one of the chief causes of our town fogs, as they have a much greater condensing power than the products of combustion of coal.

It is not claimed that these experiments prove that dry fogs in the country are produced by salt dust. The experiments only prove salt dust can produce a dry fog. As water vapour only condenses in some nucleus, it is in the highest degree probable that some nuclei, having strong affinities for water vapour, are the cause of dry fogs, and from the great amount of salt dust ever present in our atmosphere, it seems almost certain that it plays some part in the phenomena. There may be, and probably are, some other kinds of condensative nuclei which give rise to dry fogs in the country. The nature and composition of these will probably be best arrived at by analysis of the dried fog particles.

There seems to be very little doubt but that sulphur products are most powerful fog-producers, and are probably the chief cause of our town fogs. Yet, it must not be forgotten that there may be other causes at work, of which we are at present ignorant.

The paper concludes with some speculations as to the growth of ice crystals and the evaporation and condensation of aqueous vapour at water surfaces of various curvatures.

Since making the experiments above described, the fog-producing powers of the products of highly heated chloride of magnesium have been tested, and are found to possess a much greater fog-producing power than any other substance experimented with. A few grains of this salt heated in an alcohol flame, in the unsaturated air of the cellar already referred to, gave rise to a fog many times denser than that produced by the sulphur or chloride of sodium, and remained hanging in the air of the cellar for more than six hours. When the experiment is made in the saturated air of the glass receiver, the fog rapidly grows so thick that in a few minutes it is impossible to see through more than 2 or 3 inches of it. The results are similar whether the salt is heated in a flame or in the platinum tube. This intense fog-producing power of highly heated chloride of magnesium would seem to be produced by highly concentrated hydrochloric acid, produced by the decomposition of the water and chloride of magnesium.

[*Added March 8th* 1881.]

It is found that the fog-producing power of the products of combustion of sulphur are greatly increased when these are mixed with other gases and vapours. For instance, a little ammonia—another of the products of combustion of our fires—when added to the sulphurous fumes, makes the fog many times more dense than that produced by the sulphur fumes alone.

5. Note on Thermal Conductivity, and on the Effects of Temperature-Changes of Specific Heat and Conductivity on the Propagation of Plane Heat Waves. By Professor Tait.

In the great majority, at least, of investigations (experimental or mathematical) connected with conduction of heat, it has been assumed that the known changes of specific heat of metals do not require to be taken into account. Thus Ångström says, even in his paper on the *Change* of Conductivity with temperature (*Pogg.* 118, 1863):—"Da indess diese Veränderungen, soweit man sie kennt,

wenigstens innerhalb der bei den Beobachtungen vorkommenden Temperaturgränzen, nicht bedeutend sind, ... so müssen dieselben den Werth des Wärmecoefficienten nur unbedeutend afficiren können." In my paper on *Thermal and Electric Conductivity* (Trans. R.S.E., 1878), I said that "the change of specific heat with temperature would *increase* the values of k at higher temperatures, and thus reduce the change in conductivity in iron, and increase the small changes indicated for the other substances." But I had not at hand the means of applying these corrections. Recent discussions as to the comparative merits of different experimental methods have led me to investigate the amount of this effect, by the aid of the best data I could procure. A comparison of these seems to leave no doubt that the specific heat of iron *increases* by somewhere about $\frac{1}{700}$ of its amount for each degree of rise of temperature; at least from 0° to 300° C., between which limits the investigations of conductivity have hitherto been carried on.

Besides this result, which I have gathered from various scientific journals, I may adduce from my Laboratory Book for 1868 the following determinations: which were made with great care by the late Mr J. P. Nichol, by means of the method of mixtures. The nature of the process employed is such that the results *must* all err in defect, and the more so the higher the temperature. The iron was heated sometimes in oil, sometimes in paraffin.

Specific Heat of Iron.

		Mean.
15° to 100° C., . .	0·1154	0·1152
	0·1127	
	0·1158	
	0·1168	
15° to 150° C., . .	0·1193	0·1189
	0·1189	
	0·1186	
15° to 200° C., . .	0·1208	0·1213
	0·1214	
	0·1218	
15° to 250° C., . .	0·1234	0·1237
	0·1240	
15° to 300° C., . .	0·1274	0·1275
	0·1276	

From the first two of these means we find that the specific heat at 15° is 0·109 nearly, and that it increases by $\frac{1}{730}$th for each degree.

Now, Forbes' experiments on iron indicated that the quantity $\frac{k}{c}$, the ratio of the conductivity to the specific heat, *diminishes* by about $\frac{1}{550}$th part for each degree from 0° C. to 200° C. Hence it is clear that, in this case at least, the alteration of specific heat cannot be neglected in estimating that of conductivity. For it follows from the numbers just given that the diminution per 1° in the conductivity of iron is really only about $\frac{1}{2500}$th of the whole amount. My own experiments with Forbes' bars gave an average change of $\frac{k}{c}$ *less* than that due to the increase of c alone, thus indicating an increase of conductivity with rise of temperature. Ångström's result, on the other hand, is considerably greater than that of Forbes. But the range of temperatures he employed was not above forty degrees. For reasons pointed out in my paper above referred to, I consider Forbes' estimate of the value of $\frac{k}{c}$, from 0° to 150° C., to be probably very near the truth. In other metals the change of specific heat is usually less than in iron. But so is also that of $\frac{k}{c}$. It would thus appear that we cannot yet state positively that there is any metal whose conductivity becomes less as its temperature rises; and thus the long-sought analogy between thermal and electric conductivity is not likely to be realised.

In the method devised and carried out by Forbes, the change of specific heat must be attended to during the calculations. Thus we cannot, without going over again the whole numerical work connected with what he called the *Statical Curve of Cooling*, estimate accurately what will be the effect of this element upon the values of the conductivity. But we can easily show that its influence upon Ångström's results is to be calculated, at least approximately, by the simple process above.

To avoid the error introduced by supposing rate of surface loss to be proportional to v, we take (instead of a bar) a plane slab heated and cooled periodically over one surface.

The equation for the consequent distribution of temperature is

$$c\frac{dv}{dt} = \frac{d}{dx}\left(k\frac{dv}{dx}\right).$$

If we assume

$$c = c_0(1 + \alpha v),$$
$$k = k_0(1 - \beta v),$$

where α and β are small positive constants;

and put

$$\kappa = \frac{k_0}{c_0},$$
$$v = u + \omega,$$

where ω depends upon first powers of α and β only, higher powers being neglected; the equation splits into two as follows:—

$$\frac{du}{dt} = \kappa\frac{d^2u}{dx^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1).$$

$$\frac{d\omega}{dt} - \kappa\frac{d^2\omega}{dx^2} = -\kappa(\alpha + \beta)u\frac{d^2u}{dx^2} - \kappa\beta\left(\frac{du}{dx}\right)^2 \quad . \quad . \quad . \quad (2).$$

For our present purpose it is sufficient to take

$$u = -\mathrm{B}x + \mathrm{C}\epsilon^{-mx}\cos(2\kappa m^2t - mx),$$

which satisfies (1), and shows the ultimate effect of a persistent simple harmonic application of heat to one side of the slab, whose temperature is taken as our temporary zero; the other side being kept at the temperature $-\mathrm{B}s$, where s is the thickness of the slab. Here s must be supposed so large that $\mathrm{C}\epsilon^{-ms}$ is insensible; else the value of u would be so complicated that (2) would become unmanageable.

Substituting the above value of u in (2), and integrating, we obtain the value of ω. It consists of three parts.

We have, first, terms containing x only:—

$$\beta\mathrm{B}^2\frac{x^2}{2} + \frac{\beta}{4}\mathrm{C}^2\epsilon^{-2mx}.$$

These terms show how the mean temperature is altered throughout.

Next, we have the single term

$$\frac{\alpha + 2\beta}{4}\mathrm{C}^2\epsilon^{-2mx}\cos(4\kappa m^2t - 2mx).$$

This is a small wave of half period, which we need not farther consider.

Finally we have, as the modification of the original wave,

$$C\epsilon^{-mx}\left\{\left(\frac{\alpha-3\beta}{4}Bx+\frac{m(\alpha+\beta)}{4}Bx^2\right)\cos(2\kappa m^2t-mx)-\frac{m(\alpha+\beta)}{4}Bx^2\sin(2\kappa m^2t-mx)\right\}$$

These terms, when combined with the harmonic part of the assumed value of u, may be put in the form

$$C\epsilon^{-m_1x}\cos(2\kappa m^2t-m_2x),$$

where
$$m_1=m(1-\frac{\alpha-3\beta}{4m}B-\frac{\alpha+\beta}{4}Bx),$$

$$m_2=m(1-\frac{\alpha+\beta}{4}Bx).$$

We thus see the effects of the introduction of the quantities α and β upon the amplitude and phase of the wave; and it is evident that they are of the greater consequence the greater is the difference of mean temperature at the sides of the slab.

Hence the only legitimate mode of applying Ångström's method is to keep the mean temperature the same throughout the slab. This can easily be effected.

It is obvious, moreover, from the values of m_1 and m_2 above, that Ångström's method gives the value of $\frac{k}{c}$ for the mean of the mean temperatures indicated by the two thermometers. Only, there is always the extraneous factor

$$1+\frac{\alpha-3\beta}{4m}B$$

which is usually very nearly unity.

I have worked out by the above method the case of two harmonic waves (in the value of u), one of half the period of the other. New terms are thus introduced into m_1 and m_2. They are such as to seriously affect the values of these quantities when x is small, but they rapidly diminish by increase of x.

If the new term in u be

$$D\epsilon^{-mx\sqrt{2}}\cos(4\kappa m^2t-mx\sqrt{2}+E),$$

the additional terms in m_1 are

$$-\frac{\alpha+\beta}{4m}D\epsilon^{-mx\sqrt{2}}\sin X-\frac{\beta}{2\sqrt{2}-1}\frac{D}{m}\epsilon^{-mx\sqrt{2}}\cos X.$$

Those in m_2 are formed from these by making the first term positive, and interchanging the sine and cosine of

$$X=mx(\sqrt{2}+1)-E.$$

It appears from this investigation that Ångström's method, when applied with proper precautions, is theoretically capable of giving very good results. But it is probable that, in practice, the thermometers will have to be supplanted by thermoelectric junctions and a good dead-beat galvanometer. The best thermometers, when employed for rapidly varying temperatures, work by sudden starts.

6. Note on a Simple Method of showing the Diminution of Surface Tension in Water by Heat. By Prof. Tait.

A hot bar of iron was brought near the surface of a thin sheet of water covered with Lycopodium seed. The effect was precisely similar to that produced by ether vapour.

7. On the Cell-Walls of Hepatic Cells. By John Berry Haycraft, M.B., B.Sc., F.R.S.E., Senior Demonstrator of Physiology in the University of Edinburgh.

Since Henle and Purkinje first described the cells which form the great mass of the liver, microscopists have maintained that these are what are termed "naked protoplasts"—that is, they possess, like the white blood corpuscle, no differentiated cell-walls. I may mention the names of Dr Lionel Beale, Ewald Hering ("Stricker's Histology," section on the Liver), and Dr Klein ("Atlas of Histology"), who all agree in denying its existence. Indeed, the absence of this structure is emphatically insisted upon in most works on microscopical anatomy.

If a liver-cell be examined with a power of about 300 diameters, it is seen to be a granular mass, of a somewhat spherical shape, containing a very distinct nucleus and nucleolus. The granules are but the optical expression of a delicate reticulum or stroma, which may be seen as such on using a higher power.

If a section of hardened liver be examined, the cells are seen to be polygonal from mutual compression, and both in the hardened and fresh condition they are bounded by a distinct and well-defined contour.

Nevertheless, there is nothing which would lead an observer to

say that they are enclosed in cell-membranes, however well the lens be focused and the light adjusted. No doubt, the well-defined border would suggest such a structure, but it cannot be seen.

Because no membrane is apparent, it does not follow that one may not exist. If a glass tube be filled with water, and held between the light and the eye of the observer, the column of water will appear thicker than it really is. This depends upon the fact that the refractive index of the glass is greater than that of the water. Now, it will be easily seen that the glass tube might be of such a thickness that the column of water will appear as thick as the outer border of the tube itself; in fact, the tube will be no longer seen. In the case of the liver-cell, a like explanation may account for the apparent absence of a structure, the presence of which the sharp contour, remaining so even after distortion of the cell, would seem to suggest. These considerations led me to an investigation of the subject, and I have been able to demonstrate the existence of an investing membrane by a very simple procedure. With the point of a scalpel a scraping is taken from the unhardened liver of an ox; this is mixed on a glass slide with a small drop of magenta fluid, and it is then covered. A slip of blotting paper is folded and refolded until a thick square pad is formed, which is placed over the cover-glass. With the handle of a needle or a pencil pressure is applied through the pad to the preparation, or it may be hammered, for there is little fear of breaking the cover-glass, the pressure being diffused through the paper. The object may be now examined with a power of 400 diameters. If the pressure has been too great all the cells will have been destroyed, and the whole field will be covered by a magenta-stained débris, in which disengaged nuclei are seen, in this case the preparation is of little use, and a fresh trial must be made. If successful, unbroken cells will be seen at the border of the cover-glass, a granular mass in the centre, and midway between the centre and border many half-broken ones, in which latter the most satisfactory evidence of the existence of the cell-membrane is to be sought. If one of these be examined, a granular mass will be seen projecting from the rent, or in close proximity to it. This is part of the contents of the cell which has been squeezed through the aperture. Generally, the cell still contains its nucleus, surrounded by the greater mass of the protoplasm.

If the border of the tear be now examined (a $\frac{1}{10}$th or $\frac{1}{12}$th immersion lens is here desirable), a beautiful investing membrane may be seen projecting, often for some distance from the rent. It can be traced on to the cell itself, and is evidently the projecting lip of a membrane which invests it, and which has been torn through at this part. Often, again, one may see the collapsed membranous bags, containing merely the nucleus and a very small portion of the granular protoplasm which filled it, and which may now be seen scattered around.

That the investing membrane or cell-wall is very thin, it is needless to say; yet, when demonstrated by the above method, it can most clearly be made out, and in almost every preparation several entire but empty cell-walls may be seen about the field, showing that, although very fine, they are tough and resisting. Scattered among the liver-cells other tissue elements are to be seen. There are blood corpuscles, both white and coloured, and connective tissue corpuscles, the protoplasm of which is deeply tinted by the magenta. Torn capillaries are also to be seen, and they may at first sight be mistaken for the cell-walls which have been described above. There should be, however, no difficulty in recognising their tubular shape, and the fact that they have in these walls tissue which is tinted with the magenta. This is the protoplasm of the so-called nuclei of the epithelial plates of which they are composed.

I have been able to demonstrate these facts in the human liver and in that of the rabbit, as well as in the ox. The existence of the investing membrane is probably universal.

The addition of magenta is not necessary, although it is a great help, for the same points can be shown without its use. Of course a fresh preparation of the liver must be taken for examination, for it is conceivable that the hardening fluid might of itself produce a condensed outer layer which would simulate a membrane.

BUSINESS.

Mr Walter Whitehead, Mr A. H. Anglin, Mr J. A. Harvie Brown, Dr W. A. Herdman, Mr Thomas William Rumble, and Mr Robert Lawson, were balloted for and declared duly elected Fellows of the Society.